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TOOL AND DIE DESIGN  
FOR BEGINNERS

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# TOOL AND DIE DESIGN FOR BEGINNERS

A PRACTICAL HANDBOOK FOR THE BEGINNER IN THE FIELDS  
OF TOOL DESIGN, DIE MAKING, AND METAL STAMP-  
ING, WITH TYPICAL PROBLEMS CARE-  
FULLY ANALYZED

BY

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*ILLUSTRATED*

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AMERICAN TECHNICAL SOCIETY  
CHICAGO, U. S. A.

1917

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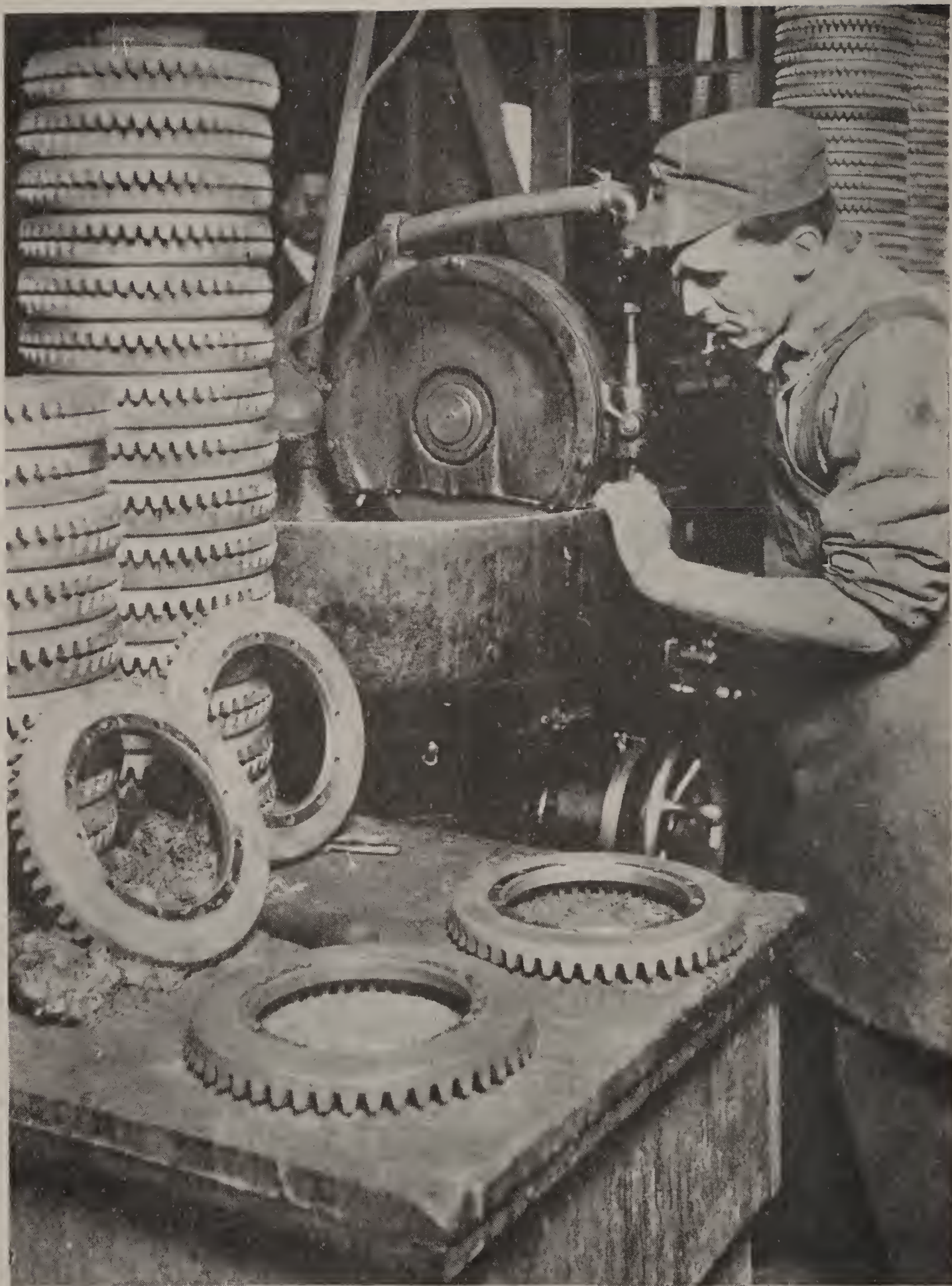
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# INTRODUCTION

NOTHING has been more influential in the development of modern shop practice than the mechanical process called "tooling up". Time was when each piece of work was treated as a whole and built from start to finish before any other piece of work was taken up. Gradually things were worked out in multiple and the complete device was finally assembled in tens or hundreds.

¶ Today, for any job of sufficient size, the design of the device is first worked out in detail, and possibly an experimental machine built. Perhaps many changes will be made in this trial machine, but when the design has been approved, the working drawings are turned over to an expert tool designer to work out the most economical method of manufacturing the device in large quantities. The tool designer studies the drawings and lays out his work with extreme care. He calls for a jig here, a die for a stamping there; he designs what seem like innumerable fixtures for the various processes of the job and gives instructions to his men how to make these appliances. After what might be considered a long and expensive process, the "tooling up" is done, and, with his well-equipped machine shop, the manufacturer is now prepared to turn out the parts of this particular device in thousands and ten-thousands. Every part is so built that it exactly fits into the whole without a break, and the assembling of the parts is the last step in this series of operations which make up modern production manufacturing.

¶ The author of this little work is a skilled tool designer and speaks from a long experience in this field. He takes several typical examples and carries out carefully the various steps, from receiving the plans to the completion of the job. The publishers feel that this book is a worthy contribution to technical literature and hope that it will prove of distinct value to the trained man as well as to those who desire merely to keep up with the times.



ROTARY SURFACE GRINDER GRINDING HIGH-CARBON STEEL GEARS  
*Courtesy of Heald Machine Company, Worcester, Massachusetts*

# CONTENTS

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## PART I—TOOL DESIGN

### SELECTION OF TYPE OF TOOLS

	PAGE
Tools for production of flatiron. . . . .	1
Method of finishing flatiron base. . . . .	1
Drilling. . . . .	5
Turning special bolt. . . . .	6
Forming flatiron handle bracket. . . . .	6
Pressing flatiron top. . . . .	8
Piercing die. . . . .	12
Requisites of designer. . . . .	13

### PUNCHES AND DIES

Blanking. . . . .	13
Functions. . . . .	13
Piercing-and-blanking die. . . . .	13
Sub-press die. . . . .	16
Combination die. . . . .	17
Drawing and forming. . . . .	19
Simple drawing die. . . . .	19
Blanking-and-drawing die. . . . .	20
Deep drawing die. . . . .	26
Shaving die. . . . .	27
Embossing die. . . . .	30
Extruding die. . . . .	30
Forming die. . . . .	31

### JIGS AND FIXTURES

Purposes. . . . .	35
Drilling fixtures. . . . .	35
Proper relation of operations. . . . .	38
Essentials in design. . . . .	39
Devices for rapid operation. . . . .	39
Boring and milling jigs. . . . .	43

# CONTENTS

## GAGES

	PAGE
Classification and usage. . . . .	44
Bench micrometer. . . . .	49

## SUCCESSFUL DESIGNING

Problem of sequence of operations. . . . .	49
Manner of holding work. . . . .	51
Method of machining. . . . .	54
Conditions for accuracy. . . . .	55
Outlining methods. . . . .	56
Design of product. . . . .	57
Collaboration. . . . .	58
Observation. . . . .	59

## PART II—DIES AND SHEET-METAL STAMPING

### BLANKING AND SHEARING TYPES

Making simple punch and die. . . . .	2
Size factor. . . . .	2
Sequence of operations. . . . .	3
Question of steel. . . . .	7
Preparing die block. . . . .	8
Laying out die. . . . .	10
Shaping of die. . . . .	11
Hardening of die. . . . .	15
Finishing of die. . . . .	16
Laying out punch. . . . .	16
Forming of punch. . . . .	17
Die shoe. . . . .	20
Sub-press dies. . . . .	20
Typical features. . . . .	20
Making press body. . . . .	22
Making plunger. . . . .	24
Making small parts. . . . .	25
Use of special cutters. . . . .	27
Fitting piercing punches and dies. . . . .	28
Placing round holes. . . . .	29
Assembling parts. . . . .	31
Sectional dies. . . . .	32
Advantages. . . . .	32

## CONTENTS

Sectional dies (continued)	PAGE
Laying out die. . . . .	32
Shaping of die. . . . .	33
Construction requirements. . . . .	34
Making of die. . . . .	36
Attaching piercing punches. . . . .	41
Making blanking punch. . . . .	42
Gang dies. . . . .	44
Accuracy required in making. . . . .	44
Approved method of making. . . . .	46
Shearing dies. . . . .	51
Two-punch principle. . . . .	51
Making lower punch. . . . .	54
Making upper punch. . . . .	57

## DRAWING AND FORMING TYPES

Drawing dies. . . . .	59
Finding size of blank. . . . .	59
Types of die. . . . .	60
Making combination type. . . . .	60
Operation points. . . . .	61
Method of making. . . . .	62
Forming dies. . . . .	65
Method of making. . . . .	65
Embossing dies. . . . .	65
Embossing. . . . .	65
Die sinking. . . . .	66
Jewelry dies. . . . .	68
Fluid dies. . . . .	68
Usage. . . . .	68
Operation of fluid die. . . . .	68
Substitute processes. . . . .	70
Forming of die. . . . .	71
Cutting design. . . . .	74
Drop-forging dies. . . . .	76
Typical operation. . . . .	76
Methods for saving material. . . . .	78
Shaping die block. . . . .	79
Recessing of die. . . . .	82
Completion of die. . . . .	85
Dies for trimming. . . . .	86



INGERSOLL 72-INCH FOUR-HEAD MILLING MACHINE MILLING HEAVY CASTINGS  
*Courtesy of Ingersoll Milling Machine Company, Rockford, Illinois*

# PART I

## TOOL DESIGN

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### TYPES OF TOOLS

**Salient Features.** The purpose of this article is to set forth the most modern design of tools generally used, such as jigs, fixtures, punches and dies, etc., and why they are used, together with the degree of accuracy that may be expected in the manufactured article when made by these tools in the hands of an unskilled operator. There is such a vast difference in the methods and the degrees of accuracy required in the manufacture of harvesting machinery and of watches, that it precludes all possibility of establishing a standard design of tools. However, by closely studying the designs and the reasons for employing certain tools for certain operations, one will be able to decide which tools are best adapted for the various operations on the contemplated article of manufacture.

### SELECTION OF TYPE

**Tools for Production of Flatiron.** Before taking up the study of the various designs of the many different tools, it is best that we first understand why certain tools are used, that is, why a jig is used instead of a punch and die, and *vice versa*. For an illustration, assume that we are about to design the tools to produce an electric flatiron, Fig. 1. This is admirably suited for our purpose, due to the fact that, in economically manufacturing this iron, there are employed blanking dies, drawing dies, forming dies, drill jigs, tapping fixtures, and milling fixtures.

**Production Basis.** The first step from the designer's point of view is to ascertain the number of irons to be manufactured yearly, as the production largely governs the design of tools. Assuming that the production will be 150,000 yearly, proceed to lay out expensive tools for rapid and economical manufacture.

**Method of Finishing Flatiron Base.** The base *a*, Fig. 2, is of cast iron, and the drawing calls for finish on top and bottom. For machining the top and bottom of the base we have available four

methods—turning; planing; grinding; or milling—the qualifications of which are as follows:

(1) Turning the surfaces in a lathe would not be considered, due to the slowness of inserting the bases in the chuck, or of turning the fixture and removing it, with the additional loss of the operator's time in waiting for the completion of the cut, but principally due to the poor surface produced by the circular cutting tool which would add to the polishing expense.

(2) Planing the surfaces would be better, for we could make two fixtures for holding a number of bases, and, while the cut is being taken on one set of bases, the operator could unload and reload

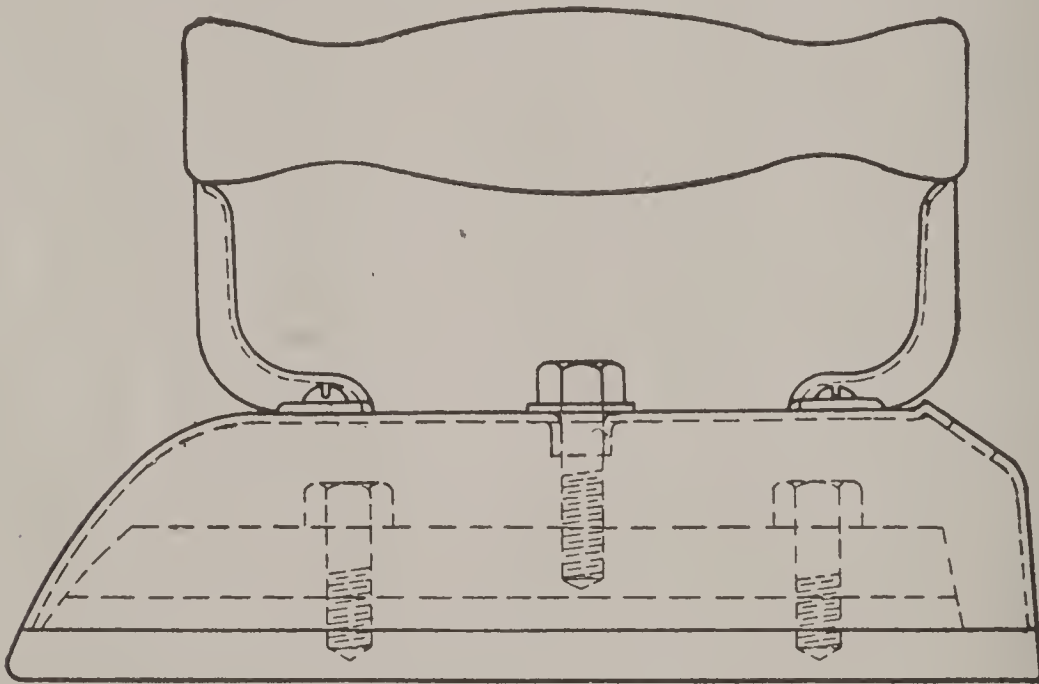


Fig. 1. Diagrammatic View of Flatiron to be Designed

the second fixture. Planers, however, are seldom found in manufacturing departments. Also the use of a single-pointed tool would not leave the desired surface when only one cut is taken.

(3) Grinding has the disadvantages found in turning, namely, waiting for the completion of the cut, and the additional disadvantage of the necessity of taking several cuts, for it is noticed that the drawing calls for a definite thickness of  $\frac{5}{8}$  inch. The castings vary in thickness, and, unless we start the cut on the thickest castings, a broken wheel will result.

(4) Milling has many advantages. First, there are a number of cutting points in the milling cutter. In addition, we can set and lock the cutter to a positive depth, insuring all bases being the

same thickness regardless of variation in thickness when in the rough. Also, the finished surface of the base will be smoother than with planing or turning.

*Milling Fixtures.* Having decided upon the milling cutter, our next problem is how to hold the bases, or which is the best type of milling fixture—largely governed by the type of milling machine we have at hand. If the miller is of the plain type, then we find

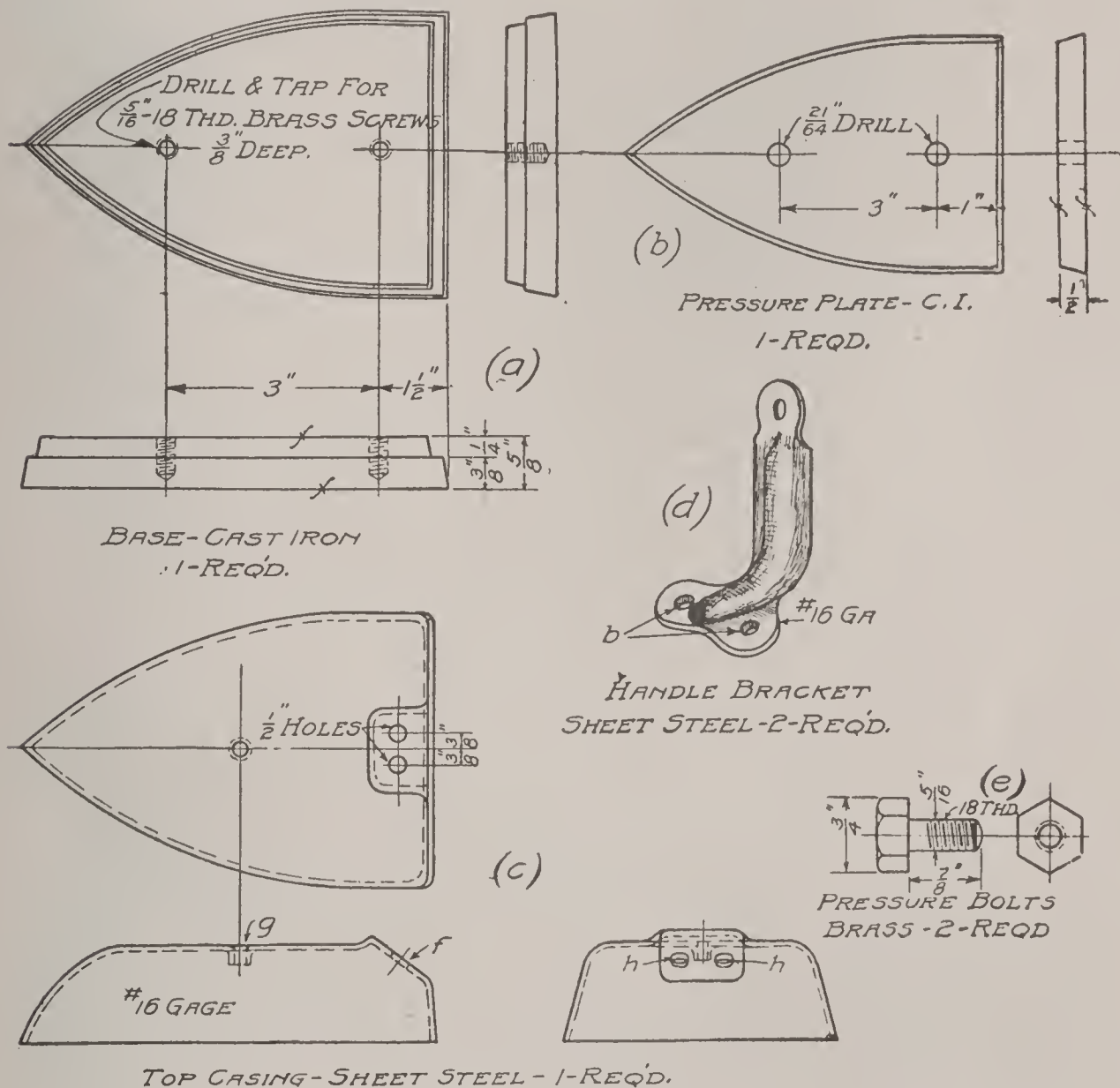


Fig. 2. Parts of Flatiron

that two milling fixtures are best adapted—one to be unloaded and loaded while the cut is being taken on a set of bases held in the other milling fixture, and the fixtures so designed as to be quickly attached on and detached from the miller.

If we have at hand a milling machine having a circular milling attachment, we have the ideal method, for then the milling fixture can be designed as shown in the upper view, Fig. 3. In operation,

the circular fixture *a* constantly revolves, as does the milling cutter *b*, and is so designed that as fast as the cutter leaves the

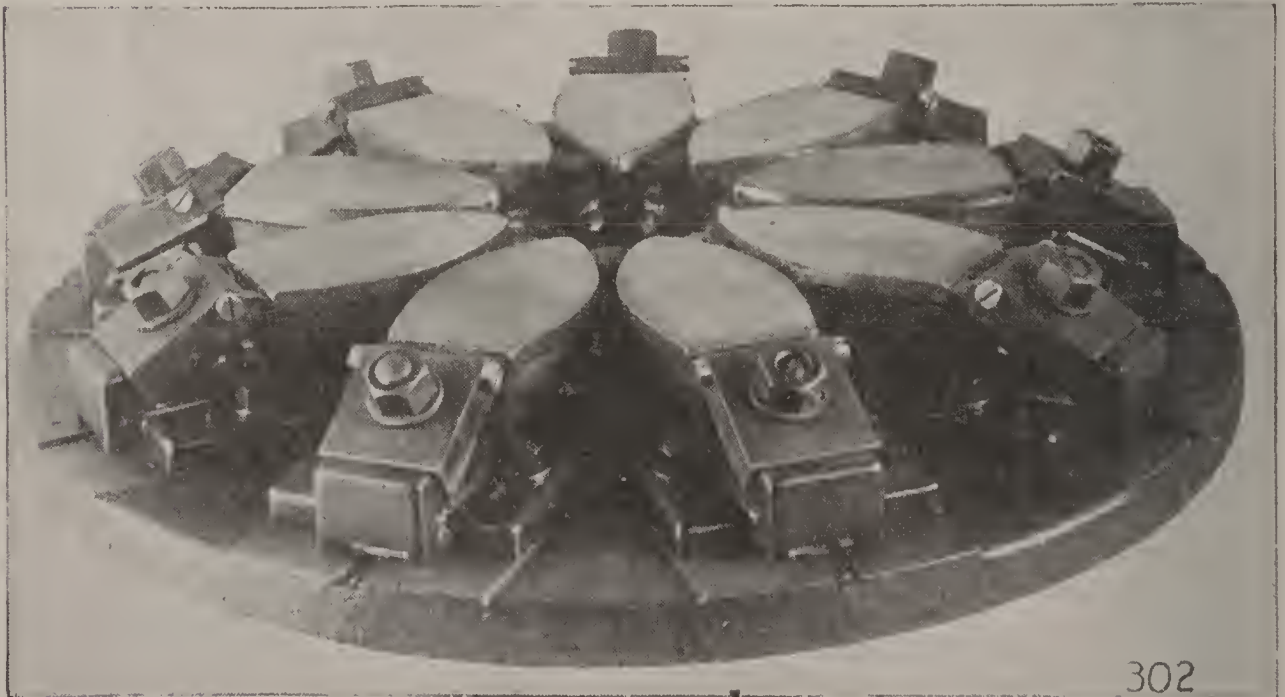
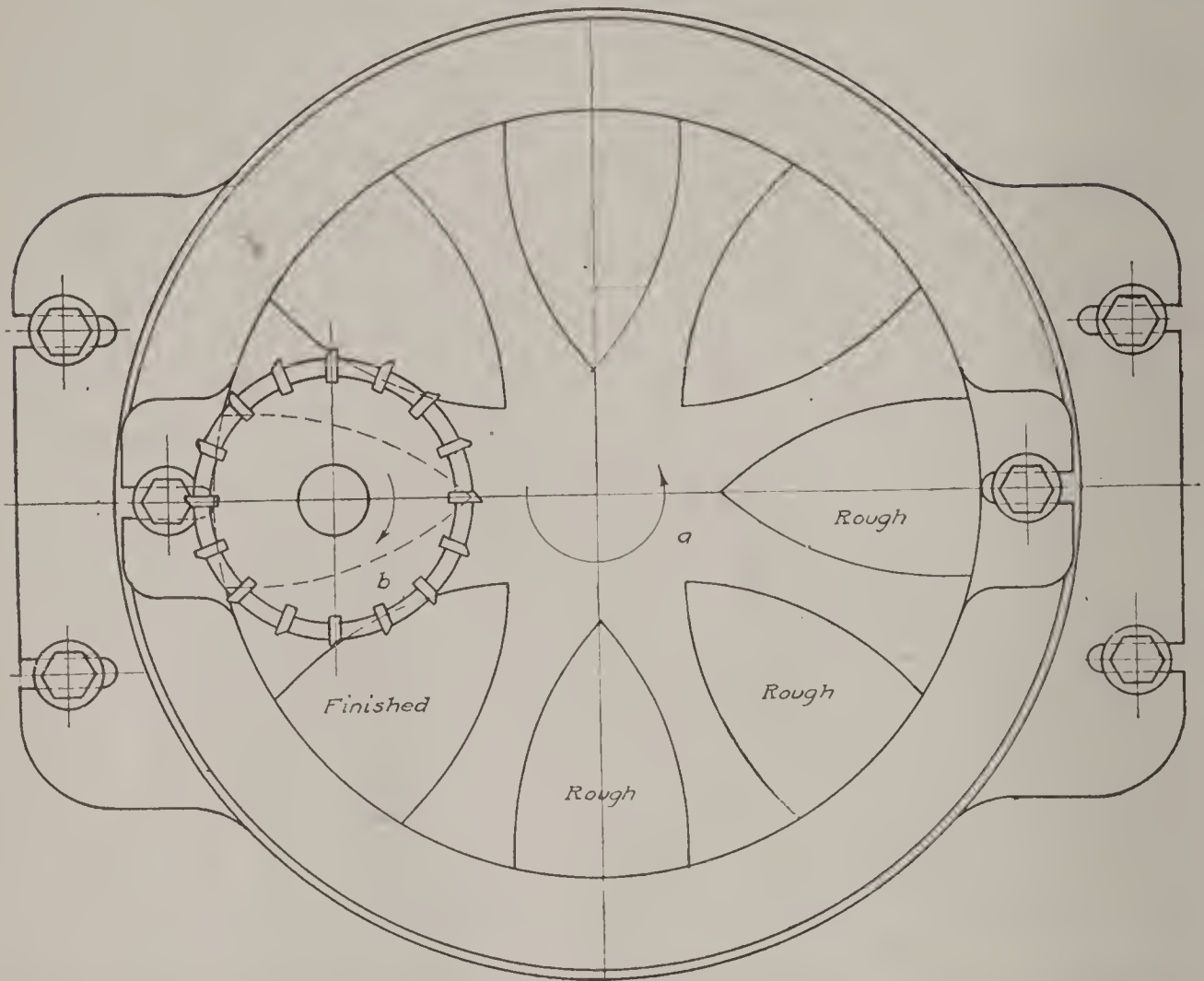


Fig. 3. View Showing Method of Finishing Polishing Surface of Iron. Lower Illustration Showing Jigs Used by Becker Milling Machine Company

surface of a base the operator can readily remove the finished base and insert a rough casting without stopping the machine. This

method proves to be the fastest because there is no lost time in stopping, starting, or changing the bases.

The same line of reasoning must be followed in working out the details of the holding devices for the bases. Speed of operation and accuracy must be uppermost in the designer's mind. The student must have in mind that although we have used only the base of the flatiron for an illustration, the methods, fixtures, and reasoning are applicable to almost any flat work that is to be surfaced. Various designs of milling fixtures will be shown later.

**Drilling. Base.** After milling the top and the bottom, the next operation on the flatiron base is drilling the two holes. For this

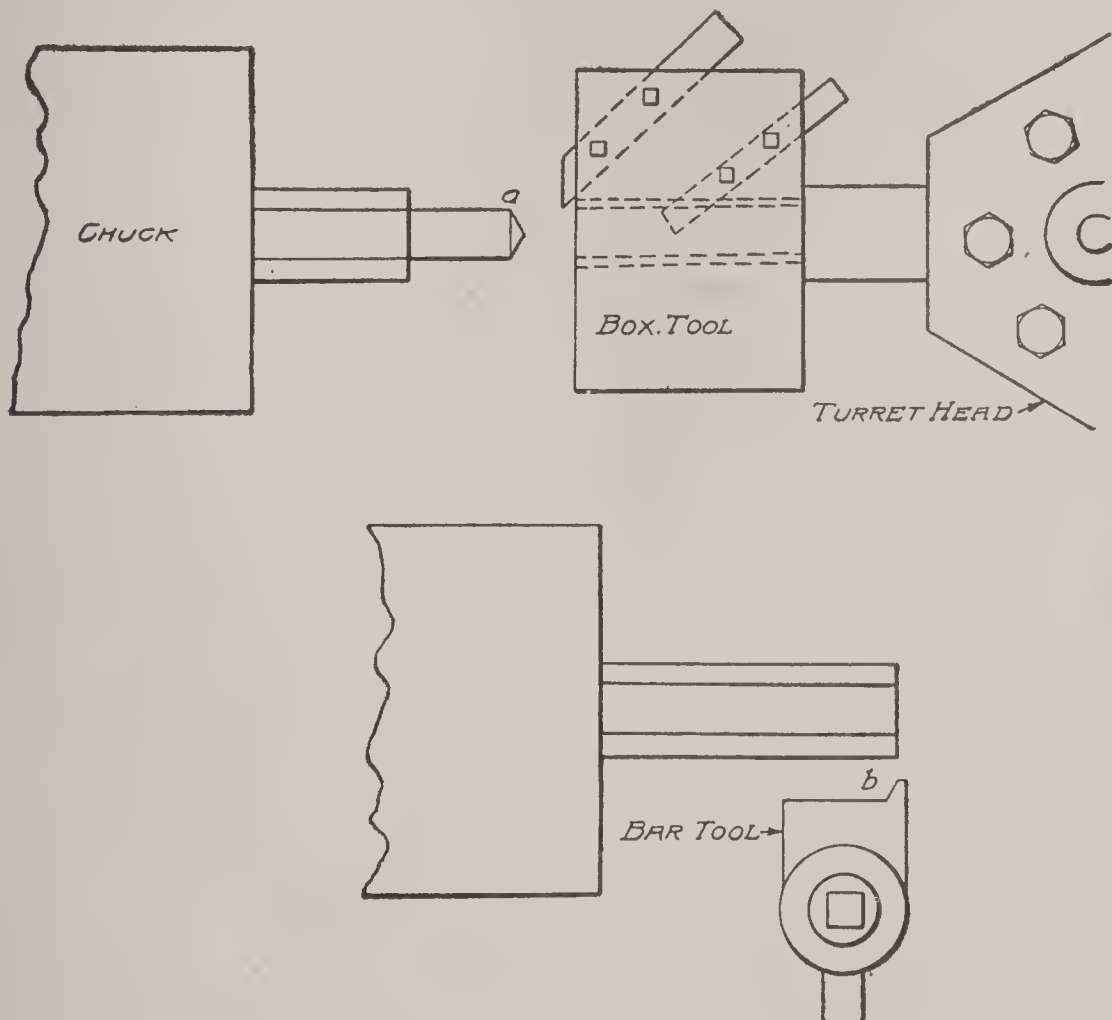


Fig. 4. Set-Up for Turning Special Bolts

operation a drill jig is used. Under the subsequent heading of Jigs and Fixtures are shown numerous types of jigs that could be used, but the open box jig, Fig. 64, used in conjunction with the multiple-spindle drill press is the most logical selection. There are no clamps or screws to operate, which means speed in operation. In order to further increase the speed of production it will be noted that the base rests on round cross-rods which prevents chips interfering and

eliminates the necessity of cleaning after each drilling operation, which is necessary on all other types of jigs. This particular type of jig is applicable only when all holes are drilled in the work at the same time, for then the work cannot shift. Accuracy closer than 0.002 inch between the holes and the edge of the work cannot be expected. If the work is of a nature that a variation of  $\frac{1}{64}$  inch is allowable, it would be cheaper to put V-spots in the pattern and drill the castings from the spots, eliminating the jigs entirely; this method should be practiced wherever feasible.

**Pressure Plate.** The pressure plate *b*, Fig. 2, is machine drilled in the same manner as the base, using the same jigs and fixtures where possible, even if necessary to design and make different holding fixtures and stops.

**Turning Special Bolt.** The pressure bolt *e*, Fig. 2, being what is termed special, we have to design tools for it. These bolts can

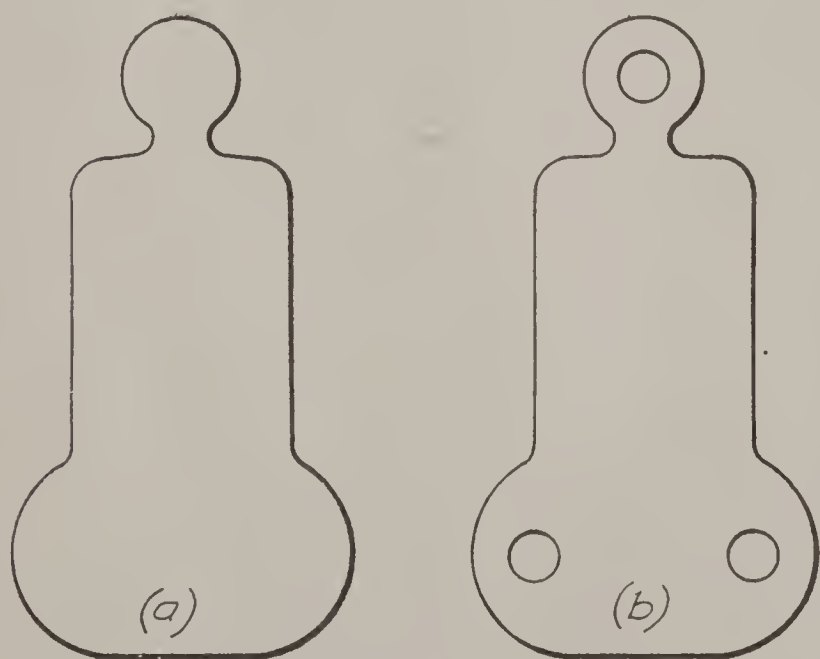


Fig. 5. Types of Blanks for Handle Bracket

be made on the automatic screw machine, or on a hand-screw machine, but in either case the hex rod should be turned to the screw size,  $\frac{5}{16}$  inch, starting from the end as shown at *a*, Fig. 4, and not with a crossbar tool as at *b*, Fig. 4; the reason being that the corners of the hex rod striking the bar tool would cause

the rod to jump and chatter. Also, it is difficult to maintain uniform diameters when using a crossbar tool, due to the spring of the rod.

**Forming Flatiron Handle Bracket.** The handle bracket *d*, Fig. 2, is of sheet steel; the machining method in vogue before the advent of the punch and die was to clamp a number of flat rectangular pieces together, and, with a formed milling cutter, to mill the pieces on one edge, then on the other, and finally to drill the holes.

**Types of Dies.** We now use punches and dies, described later, and the aim of the designer should be to complete as much of the

work in one stroke as is practicable. In Figs. 16, 18, 19, 21, and 22 are shown five different types of dies, any one of which would successfully produce the bracket. If the plain type of blanking die shown in Fig. 16 were to be used, it would produce a blank as at *a*, Fig. 5, and it would mean that the bracket would have to go through another operation for piercing the holes.

The punch and die, Fig. 18, sometimes called a follow die, also a pierce and blank, and a combination die, would produce a blank at each stroke as shown at *b*, Fig. 5. The objection found in using a combination punch and die is that the holes are pierced in one part of the strip of steel, then, when the strip is moved along until the pierced holes are directly over the blanking die, in which position the blank is punched out, errors creep in, due to the strip stock not

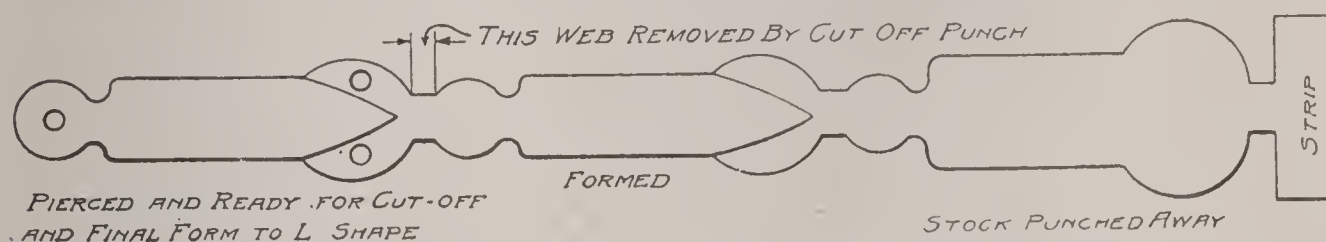


Fig. 6. Handle Bracket Shown in Three Stages of Development

lying level on the surface of the die, and resulting in the holes being improperly located in the blank.

The subpress die shown at Fig. 21 is used only for accurate work, due to its initial high cost.

To produce our bracket, we will select the punch and die shown in Fig. 22—which, by the way, is really two punches—for the following reasons: By referring to *d*, Fig. 2, we note that the bracket is formed L-shape, with a rib between the two holes *bb*. This rib will change the original center distance between the holes *bb*, therefore, it is best to pierce these holes after forming. The other advantages in using this type of die are that, instead of punching out the blank, as is the case with any other type of die, the surrounding stock is punched away, leaving the blank on the strip, Figs. 6 and 23, and a blank drops, completed, at each stroke of the press. This subject will be treated at length under Punches and Dies.

*Essential Reasoning.* The student must study and become thoroughly conversant with each type of punch and die in order to follow out the following line of reasoning when designing tools for any article:

(1) The plain blanking punch and die of the type shown in Fig. 16 should not be used, for it means several additional operations to complete the blank, also the tying up of several presses.

(2) Neither the combination, Fig. 18, nor the subpress, Fig. 21, should be used, because trouble will be experienced in maintaining the proper center distance between the holes *bb* in forming the bracket. Also the blank would drop from the die only blanked

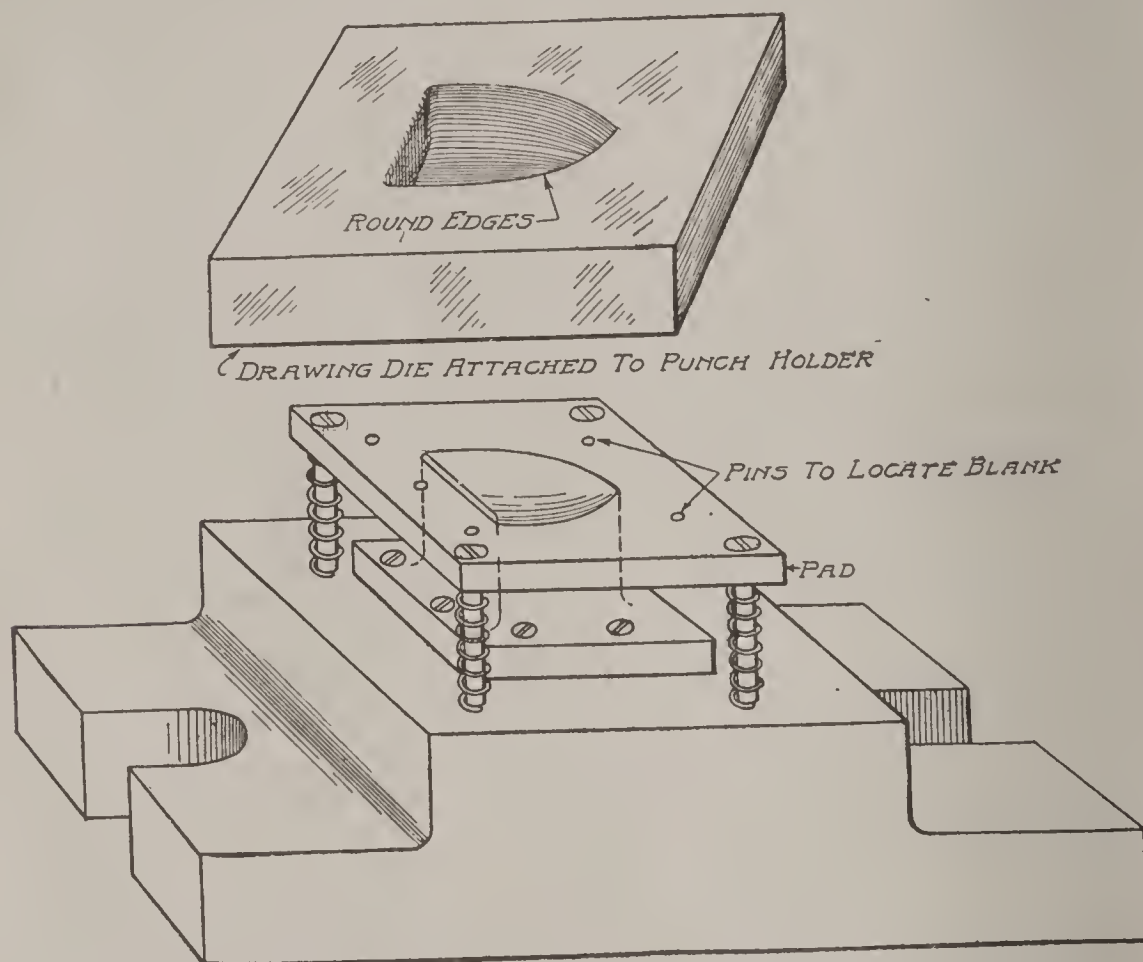


Fig. 7. Drawing Punch and Die for Flatiron Top

and pierced, which would mean additional operations and presses to complete the forming operations.

(3) The punch and die, Figs. 22 and 23, are selected because it requires but one operator and one press, and a complete bracket is produced every stroke as the result of progressive operation. This type of die, however, can only be used where a variation of 0.005 to 0.010 inch is allowable. It could properly be called combination, for it blanks, pierces, forms, and cuts off.

**Pressing Flatiron Top.** The flatiron top *c*, Fig. 2, is of sheet steel, and to produce it requires blanking, drawing, redrawing, trimming, and forming dies. To produce an irregular cup-shaped blank is one of the most difficult feats in punch-and-die work.

*Finding Blank.* The designer must work in conjunction with the tool-makers, and the drawing dies must be made first in order to find the blank, as the shop expression is. In other words, the profile of a blanking die cannot be designed, but must be found as in the following manner: Two pieces of steel of proper thickness

are cut out exactly alike, of a shape that experience alone governs, for the designer must imagine about what shape the blank should be. These two pieces may be stamped *A* and *A*, and one piece formed by putting it through the drawing punches and dies, while the other blank is kept in its flat state. If too much stock, or not enough, has been left on the blank to produce the desired cut, or, if it is not the proper shape, the shape is changed and two more blanks are made exactly alike, stamped *B* and *B*, and one of these *B* blanks is also put through the drawing dies. When the desired shape is finally obtained, the mate to the

formed blank which is accepted is used for the blanking die.

*Trimming.* If the drawing punch and die, Fig. 7, were designed to draw the flatiron top or any cup complete at one draw, the edges of the top would be irregular, as shown in *a*, Fig. 8, which would mean a slow facing operation. Therefore, the die is designed to draw the cup, say  $\frac{7}{8}$  of its depth, which makes the blank as shown at *b*, Fig. 8; then a trimming die, Fig. 9, is made to trim the edge,

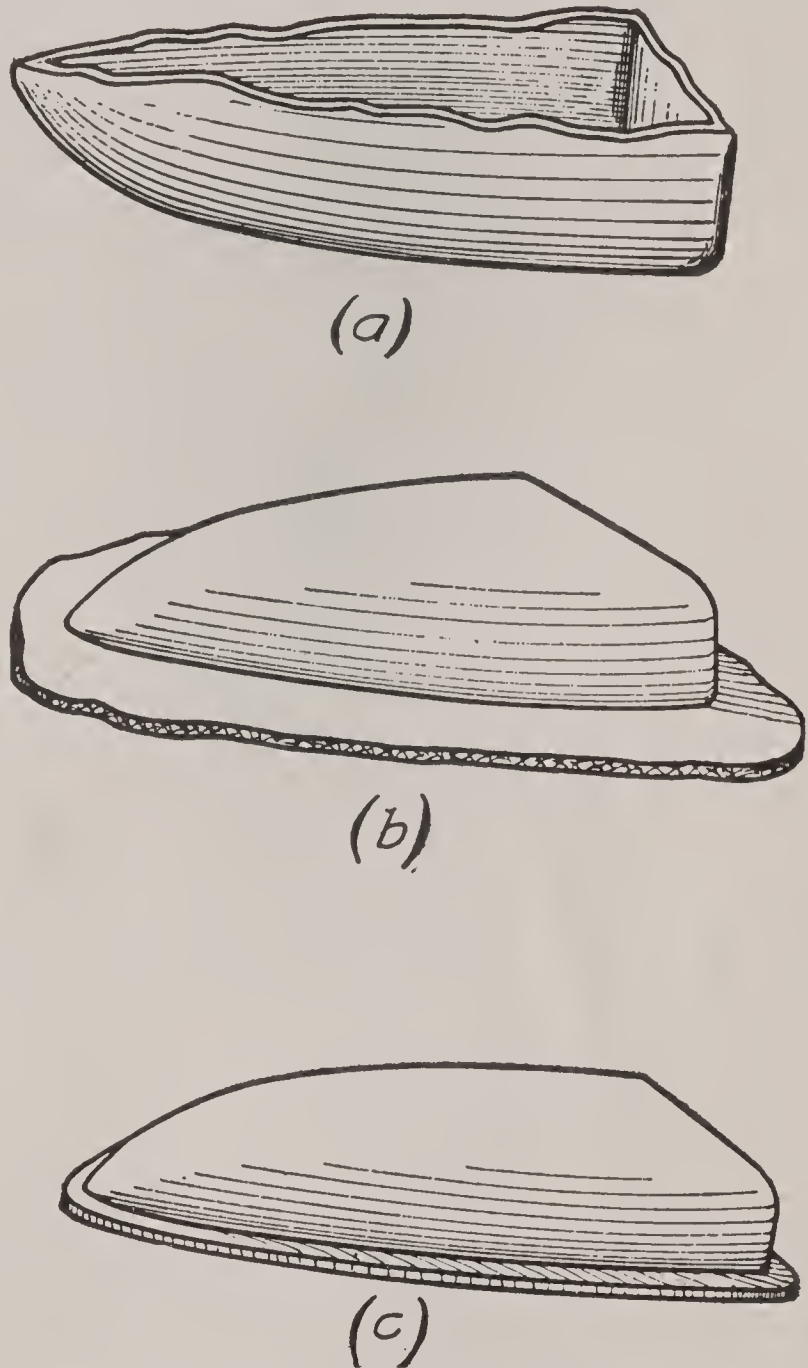


Fig. 8. Flatiron Top in Process. (a) Faulty Construction; (b) Blank as First Drawn; (c) Blank Properly Trimmed

leaving it as at *c*, Fig. 8. The punch *a*, Fig. 9, is fastened to the die shoe, which in turn is fastened to the bolster on the bed of a press,

and the punch has a shaped top section to fit inside of the cup to act as a locator. This locator *c* is made detachable to permit of grinding the top face of the punch. The trimming punch and die are nothing more than a plain blanking punch and die and derive the name from the trimming operation on the cup.

After the cup has been trimmed the  $\frac{1}{8}$ -inch margin all around the cup is uniform in width and the edges are square. The cup is then pushed through a re-drawing die, as shown in

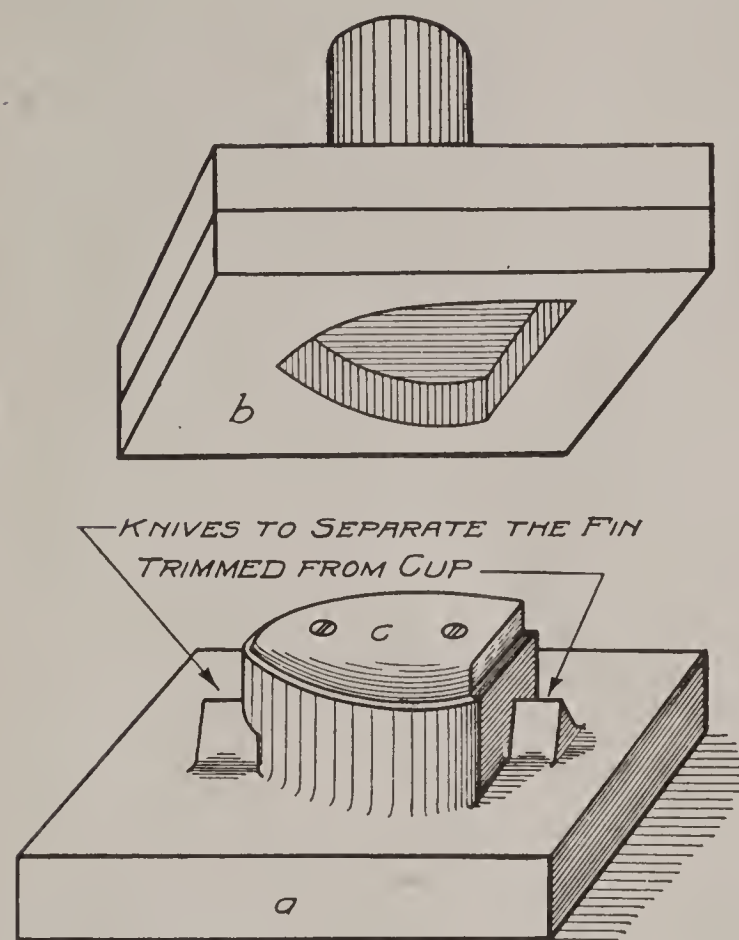


Fig. 9. Trimming Punch

the section at *a*, Fig. 10, producing the finished cup with parallel and straight edges as shown at (*b*) in the same figure.

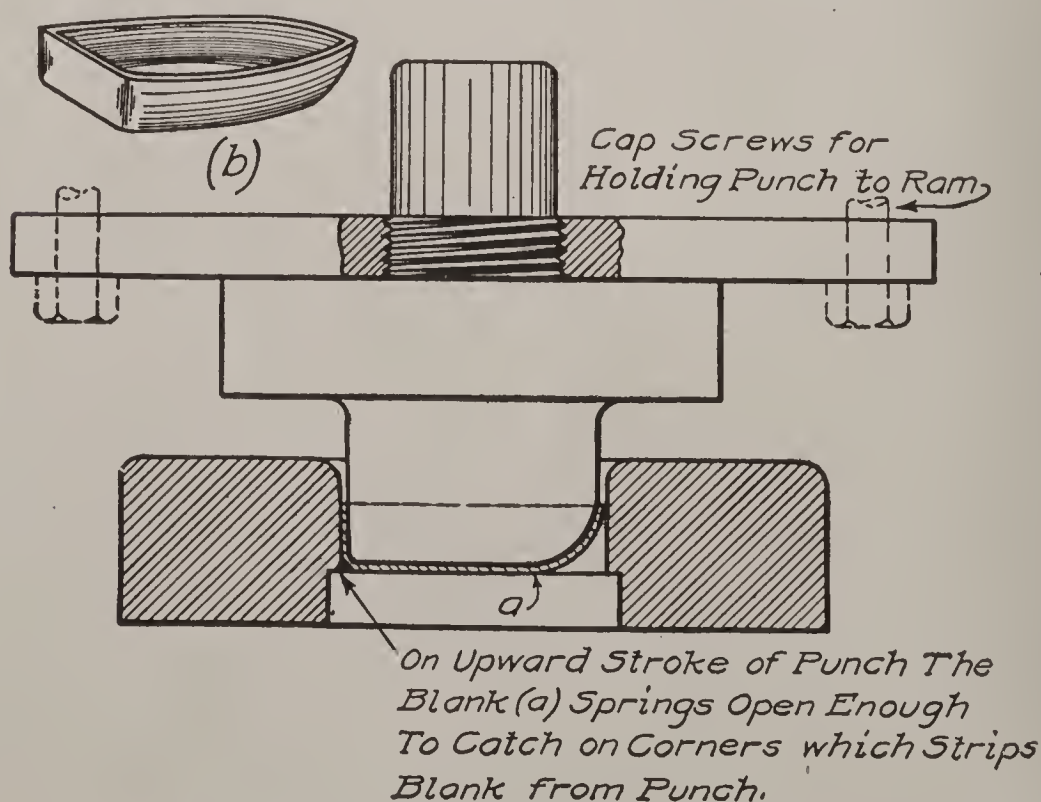


Fig. 10. Section of Redrawing Die and Finished Top

*Extruding.* When designing drawing dies to produce portions bulged from the central part of a cup, as *f* and *g*, Fig. 2, it is the best practice to design a sort of preparatory drawing die, that is, a die that will push out a surplus amount of stock but of a shape that is easy to draw, as shown in section at *a*, Fig. 11. The extruding

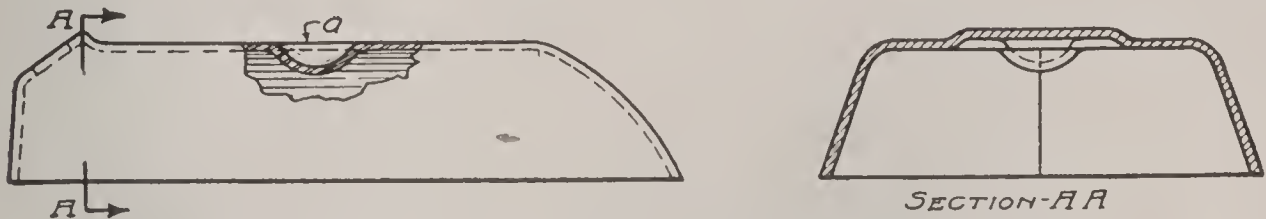


Fig. 11. Part Section of Top of Flatiron Showing Design of Bulging Portions

of metal from the center of a sheet causes that portion to stretch instead of draw, and, if there are comparatively sharp corners in the shape being extruded, the stock tears apart. For this reason a sufficient or even a surplus amount of stock is forced out, and then the forming punch and die, Fig. 12, are made to produce final shape on only the part *f*, Fig. 2, and to iron out any wrinkles or surplus stock that may have been caused by the preparatory bulging or drawing of the cup.

The die, Fig. 12, shown in section, is made in the desired shape, and the punch is made the same shape, but smaller, for it is obvious that the metal to be formed must be between the punch and the die. The extruded

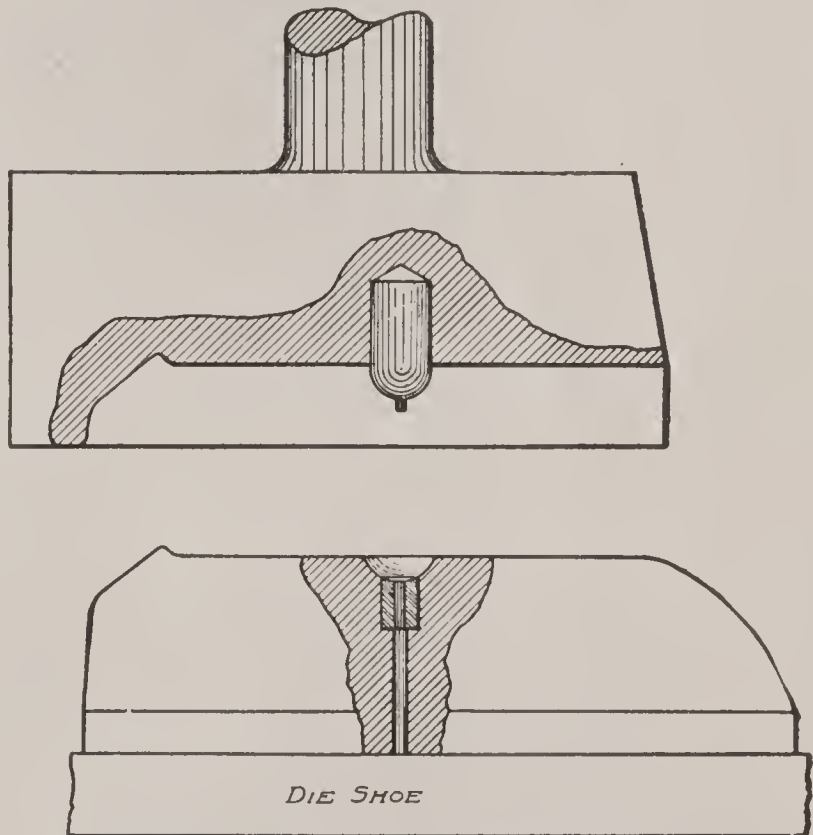


Fig. 12. Design of Punch and Die for Piercing Top

portion *g*, Fig. 2, must be pierced with a small hole as in *a*, Fig. 13, before its final drawing, and the piercing die can be placed in the same die, Fig. 12, that finishes the part *f*, the object being to save an operation of handling the cup. If the extruded portion *g*, Fig. 2, is pierced while the top of the cup is flat, there are apt to be cracks in *g* when drawn to final shape, as shown in *b*, Fig. 13.

*Sizing.* The last drawing operation on the flatiron top is to draw and size the portion *g*, Fig. 2 (c). For this operation a sizing punch and die of the form shown in Fig. 14, is employed.

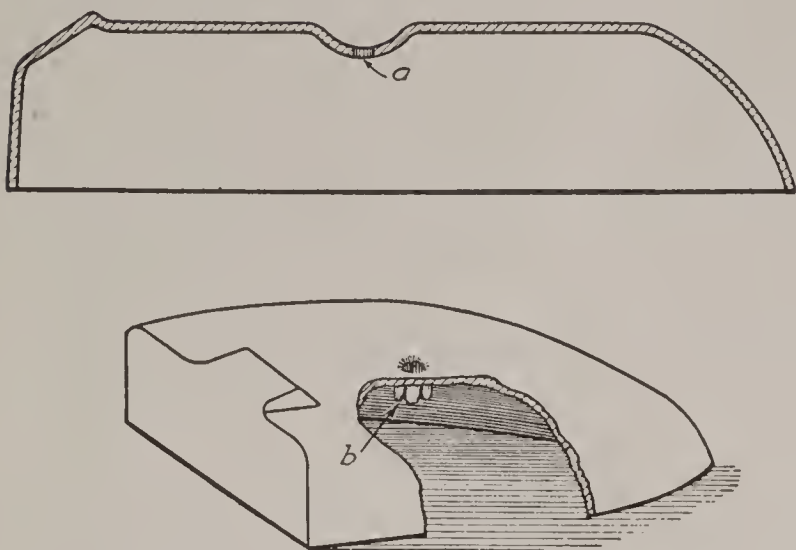


Fig. 13. Sketch Showing Possible Tearing of Metal in Punching

in a jig. But there are many advantages in punching holes in thin stock, some of which are as follows: Both holes are pierced simultaneously, insuring uniform center distances between holes, which

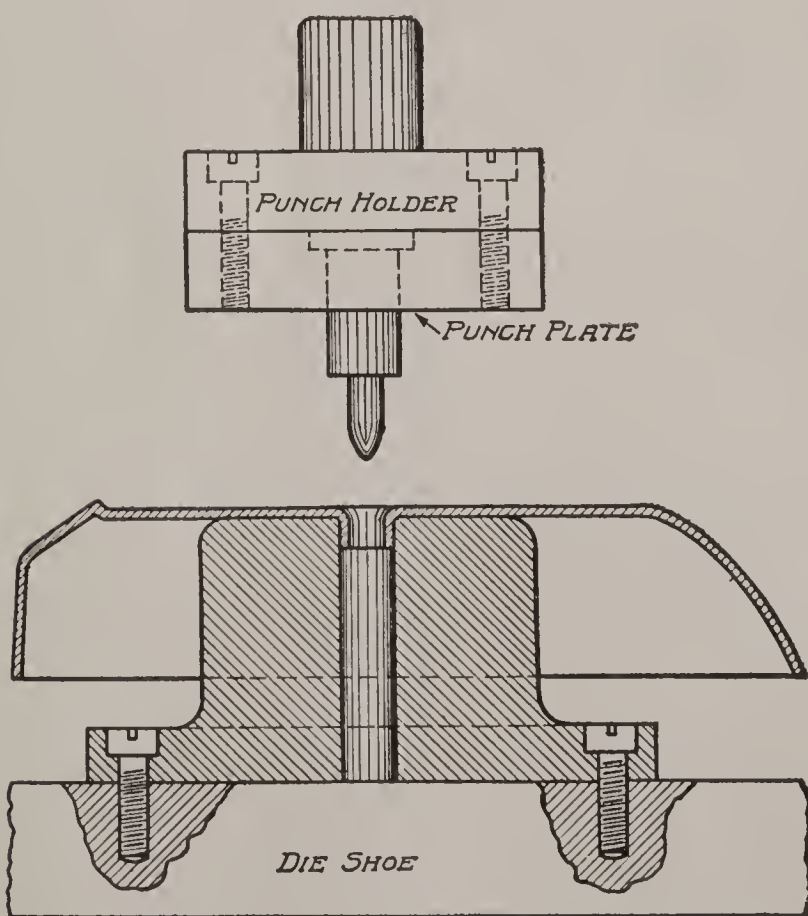


Fig. 14. Sizing Punch and Die for Flatiron Top

**Piercing Die.** A piercing die, Fig. 15, is employed for the last operation on the top, that is, for piercing the two holes *hh*, Fig. 2 (c), through which the electrodes are to come.

It will be noted that the holes *hh* could be drilled

would not be true if first one hole were drilled and then the next, because there is a slight difference in the diameters of holes in bushings and in jigs and the drill used. Another advantage of punching is that in a drilled hole there always is a decided burr protruding from the bottom edge of the hole where the drill breaks through. Another reason why a piercing die is preferable to a drill jig is that thin stock does not drill sat-

isfactorily, due to the point of the drill being clear through the sheet stock before the body of the drill enters, which causes the drill to climb from the hole, producing an irregular hole. A final

advantage is in the speed obtainable in inserting and removing the blank; there are no locking devices employed, as on jigs.

**Requisites of Designer.** The foregoing is a brief outline of how a designer must set about to design tools for any product.

He must consider the advantages of the various tools before he decides to use any particular one, for in some cases a tool not generally used for the class of work he may have at hand will prove to be best adapted for the job. After deciding which type of tool to use for a certain operation, the designer must then decide which particular style of that type of tool to use. In other words, the designer must acquaint himself with

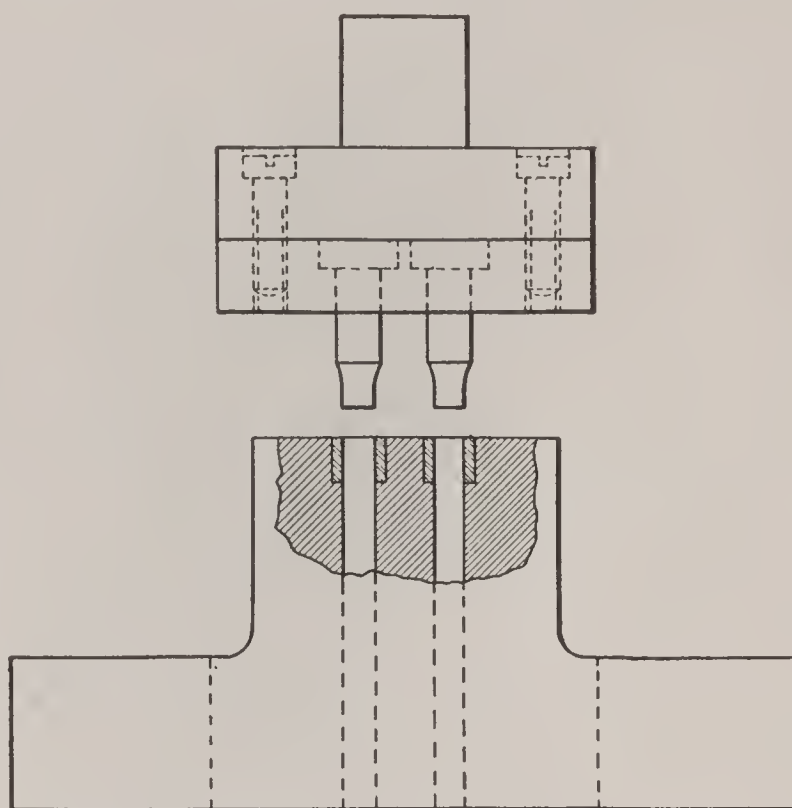


Fig. 15. Piercing Die for Two Holes in Flatiron Top

every design of tool in general use and must cultivate the faculty of designing an original tool now and then to do some particular operation which could not be done satisfactorily with the tools of ordinary design.

## PUNCHES AND DIES

### BLANKING

**Functions.** A punch and die, such as shown in Fig. 16, used to punch out from sheet stock the initial plain blank in Fig. 17, is called a blanking die. The plain blanking die has been elaborated upon so that the die can be made to do several operations prior to blanking, but as long as the desired blank is punched from the stock, regardless of prior operations on the blank, the die comes under the general classification of blanking dies.

**Piercing-and-Blanking Die.** Fig. 18 shows what is known as a piercing-and-blanking die, also cut and follow, and combination die. With this type of die no very accurate work can be expected,

for curvature in the sheet means varying distances between pierced holes. Another cause of inaccuracy is due to the fact that, in this

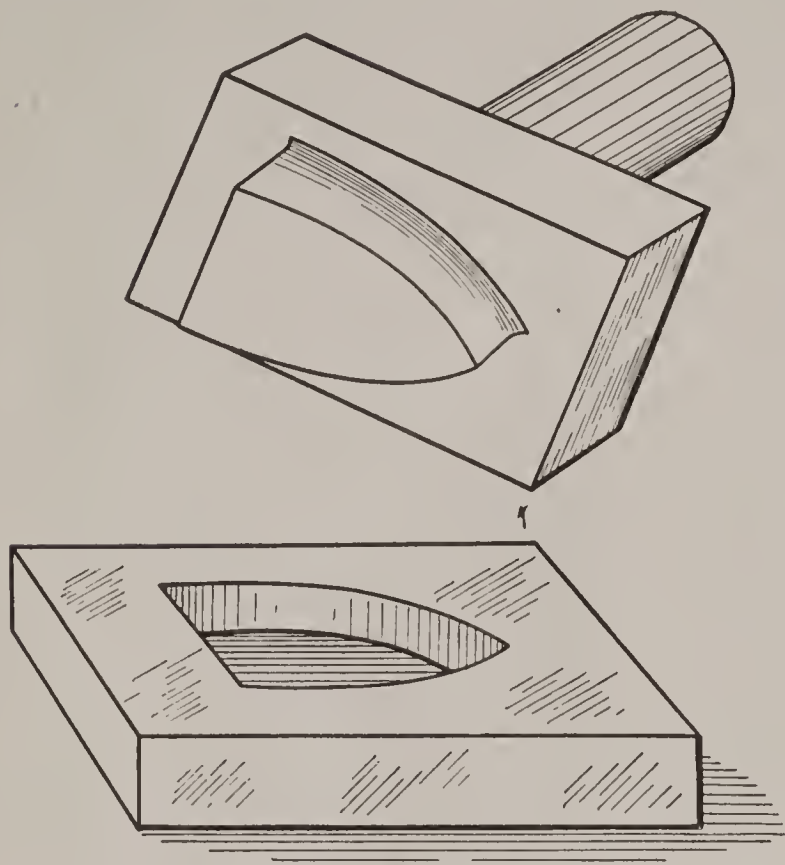


Fig. 16. Typical Blanking Die

instance, the two pierced holes in the stock are located over the blanking die by means of the pilots *aa*, and that these pilots are of necessity a trifle smaller in diameter than the holes, which allows variation in any direction. Also, curved or kinked stock straightens out when the face of the blanking punch comes in contact with it, causing the holes to become of greater distance between centers, and distorted, due to pressure

against the pilots. This die should be used only on work that does not require accuracy closer than 0.005 inch.

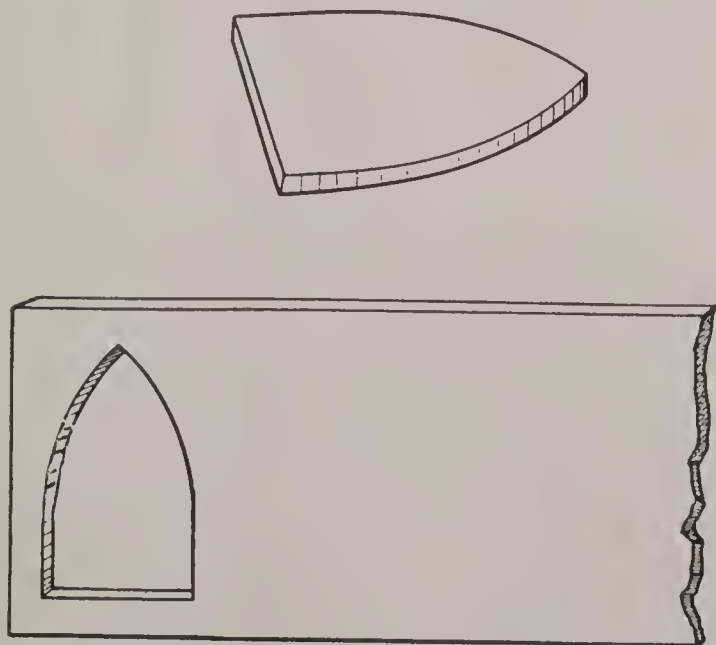


Fig. 17. Metal Sheet and Blank Cut from It by Blanking Die, Fig. 16

*Spring Stripper.* Fig. 19 shows the same design of die, with the addition of the spring stripper *a* attached to the punch plate. When the spring stripper comes in contact with curved stock on the face of the die, the spring pressure straightens the stock prior to piercing and blanking. Accuracy closer than 0.003 inch cannot be expected with this type of die.

*Hardened Bushings.*

When this type of die is to be employed for blanks over 2 inches long, the design shown in Fig. 20 should be used. The blanking section *a* is of tool steel and hardened, while the pierce section

*b* is of machinery steel and has the holes bushed with hardened steel, the objects being: a saving of expensive tool steel; a smaller piece to harden, thereby lessening the chances of cracking when hardening; and removing the possibility of center distances changing. An added advantage is in the use of the bushing which can be easily

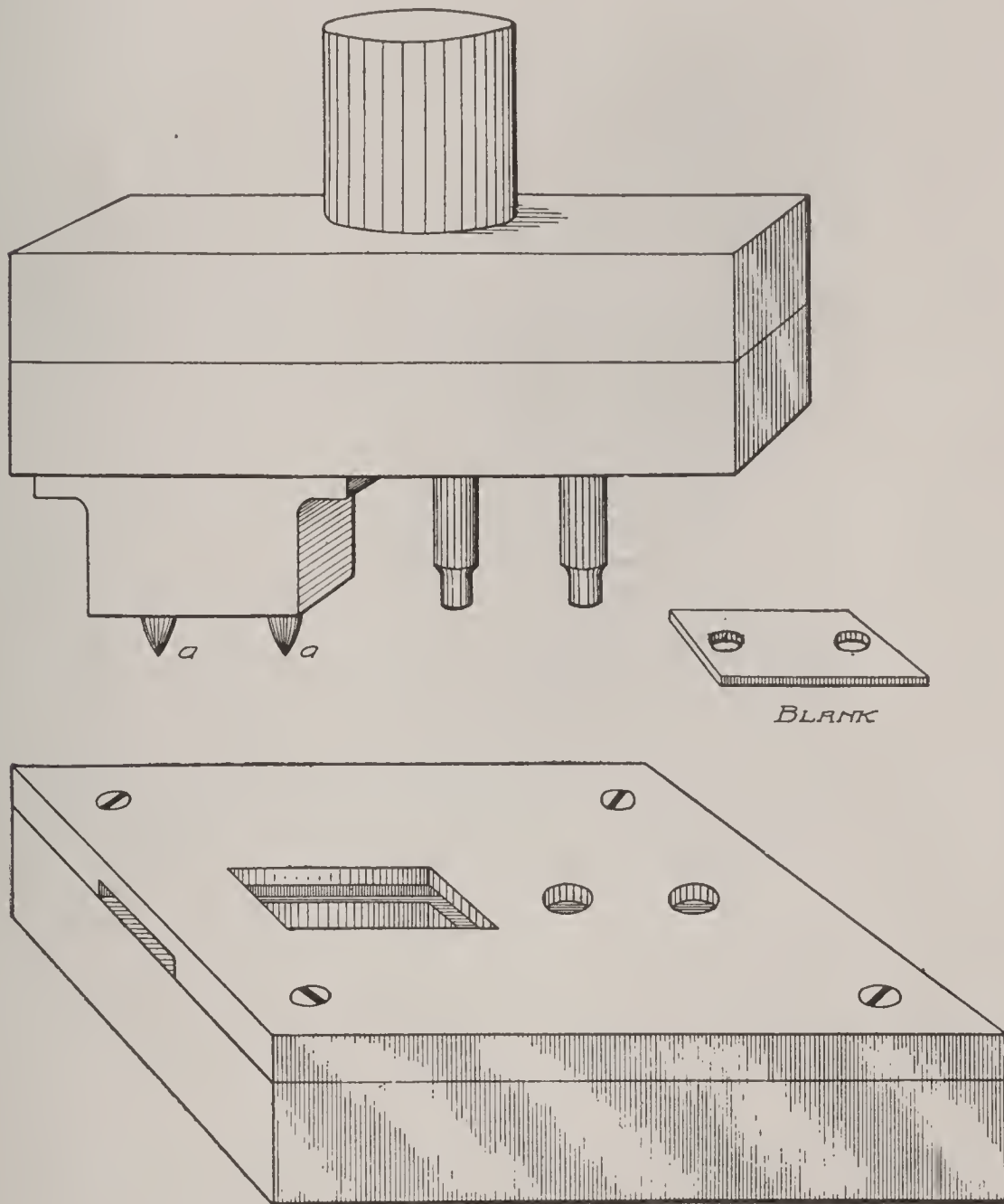


Fig. 18. Typical Piercing-and-Blanking Die

changed without annealing the die. The designer should call for bushed holes in all piercing-die holes where possible, whether of hardened tool steel or soft steel, for, if a different size hole is desired, all that is necessary is to make a new bushing.

*Punches.* Piercing punches should be designed with heads, Fig. 15, as they are the easiest to make and cannot be pushed or

pulled out of the punch plate. Using a set screw against the shank of the punch is not so good as it tends to tilt the punch.

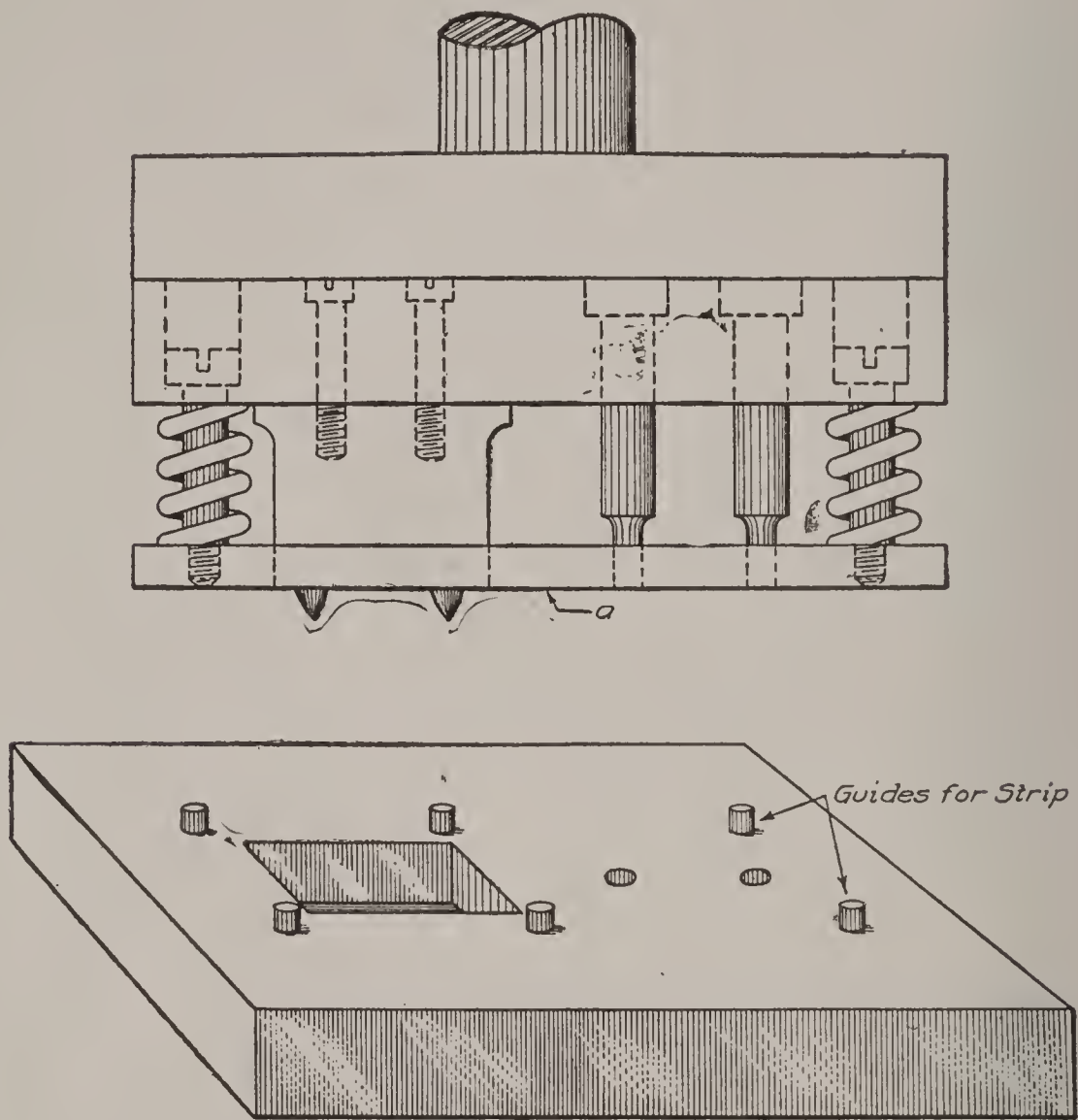


Fig. 19. Die Shown in Fig. 18 with Spring Stripper Added

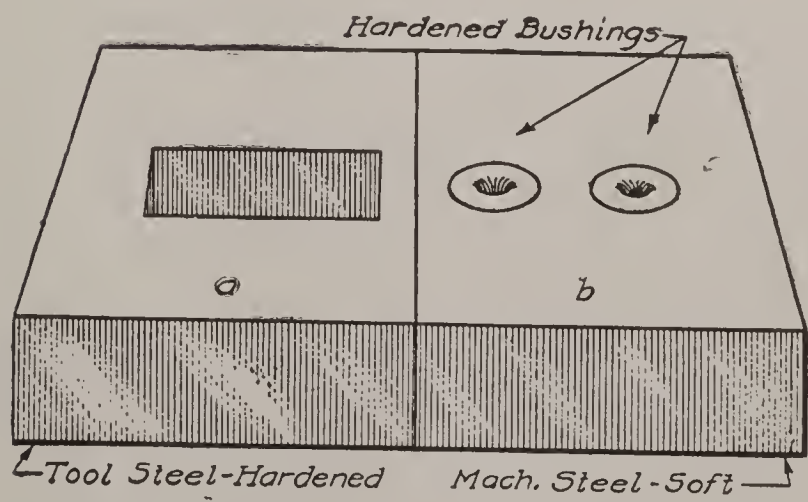


Fig. 20. Sketch Illustrating Saving in Expensive Steel by Use of Bushings

**Subpress Die.** The cross-section in Fig. 21 shows a subpress die in its simplest construction. This type produces the most accurate work of any die in the blanking class. The designer should never call for a subpress die for work that does not require

extreme accuracy; neither should he call for a piercing-and-blanking die when accuracy in the blank is required. When designing a

subpress die, care must be exercised in having the necessary rigidity in the various members, especially in the guide pins *aa*. If there is considerable work to be made requiring subpress dies, then a suitable pattern should be designed and the bodies and base made of castings.

In Tool-Making, Part III, Figs. 380, 381, and 382 show the three styles of subpress dies most generally used.

**Combination Die.** In Fig. 22, herewith, is shown a peculiar type of die that is not old enough to enjoy a name but might properly

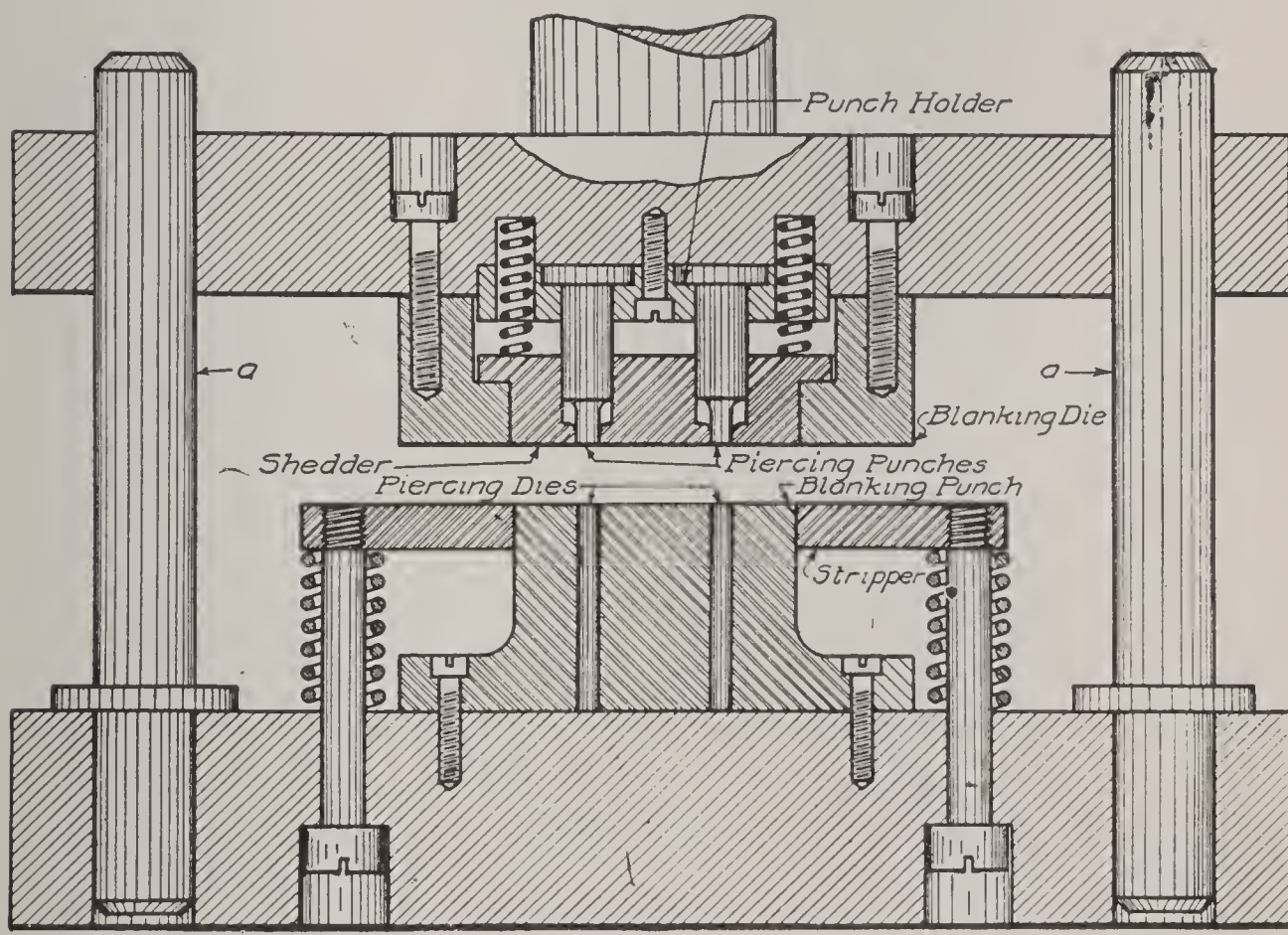
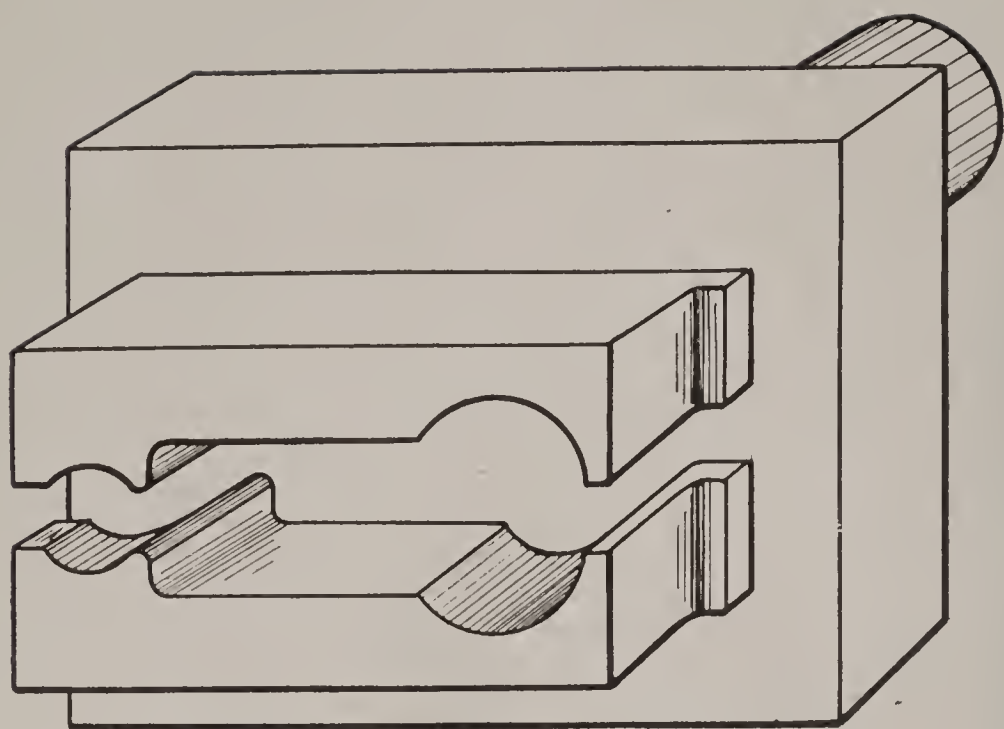


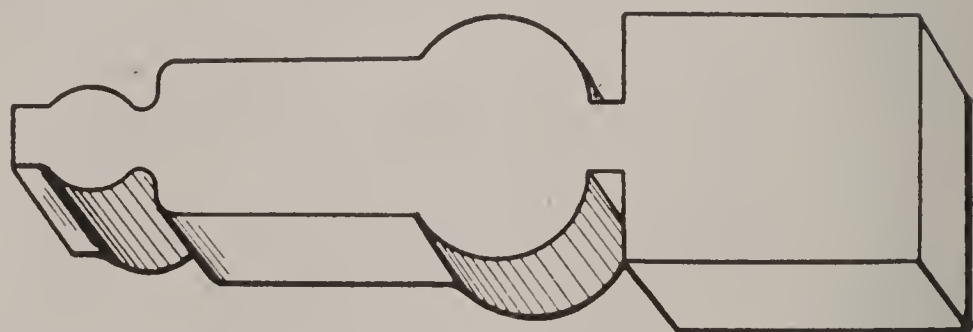
Fig. 21. Section of Typical Subpress Die

be termed a combination. The stripper is left out of the upper part to make the sketch clearer. This die differs from others in that there really is no die proper but it is made up of a number of punches. As previously stated, the stock is punched away, leaving the blank on the strip, in which position the blank can be handled for successive operations, while in reality the blank is not handled at all.

**Elaborations.** Fig. 23 shows this die elaborated to the extent of producing the profile which forms the blank, of piercing the holes, of cutting the blank from the strip, and of final-forming the blank to L-shape, all at one stroke of press. Of course, it is necessary at



*UPPER MEMBER FOR BLANKING*



*LOWER MEMBER FASTENED TO DIE SHOE.*

Fig. 22. Combination Die

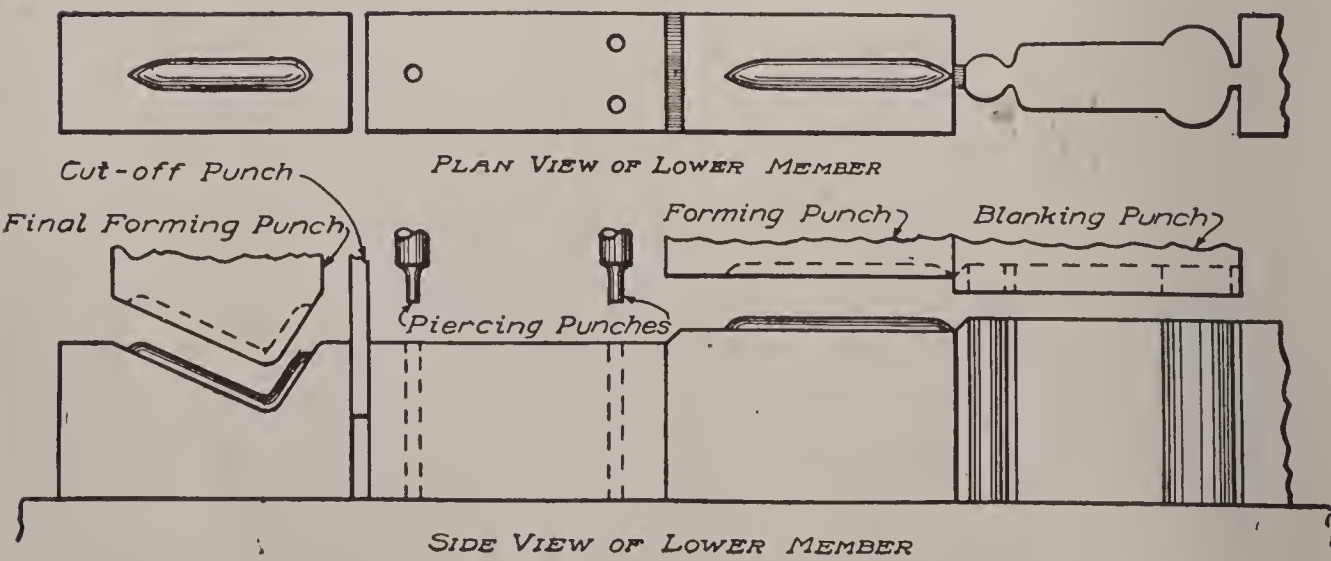


Fig. 23. Elevation and Plan of Progressive Steps in Forming Finished Blank

the start to move the strip four times, and 4 strokes of the press are required before a finished blank is severed from the strip, but thereafter, to the end of the strip, a piece, as shown in *d*, Fig. 2, is completed at each stroke.

This type of die offers untold opportunities to the designer, for cross-slides for bending some particular part can be added to the die, and the die can even be fitted with a tapping fixture actuated by gears driven by a rack attached to the punch plate, so that the desired blank can be blanked, formed, pierced, bent, tapped, cut off, and final-formed at each stroke of the press. One design of tapping fixture applicable to punch and dies is shown in Fig. 24; the vertical shaft *a*, to which the tap is attached, contains a long key by which the bevel gear rotates the tap shaft.

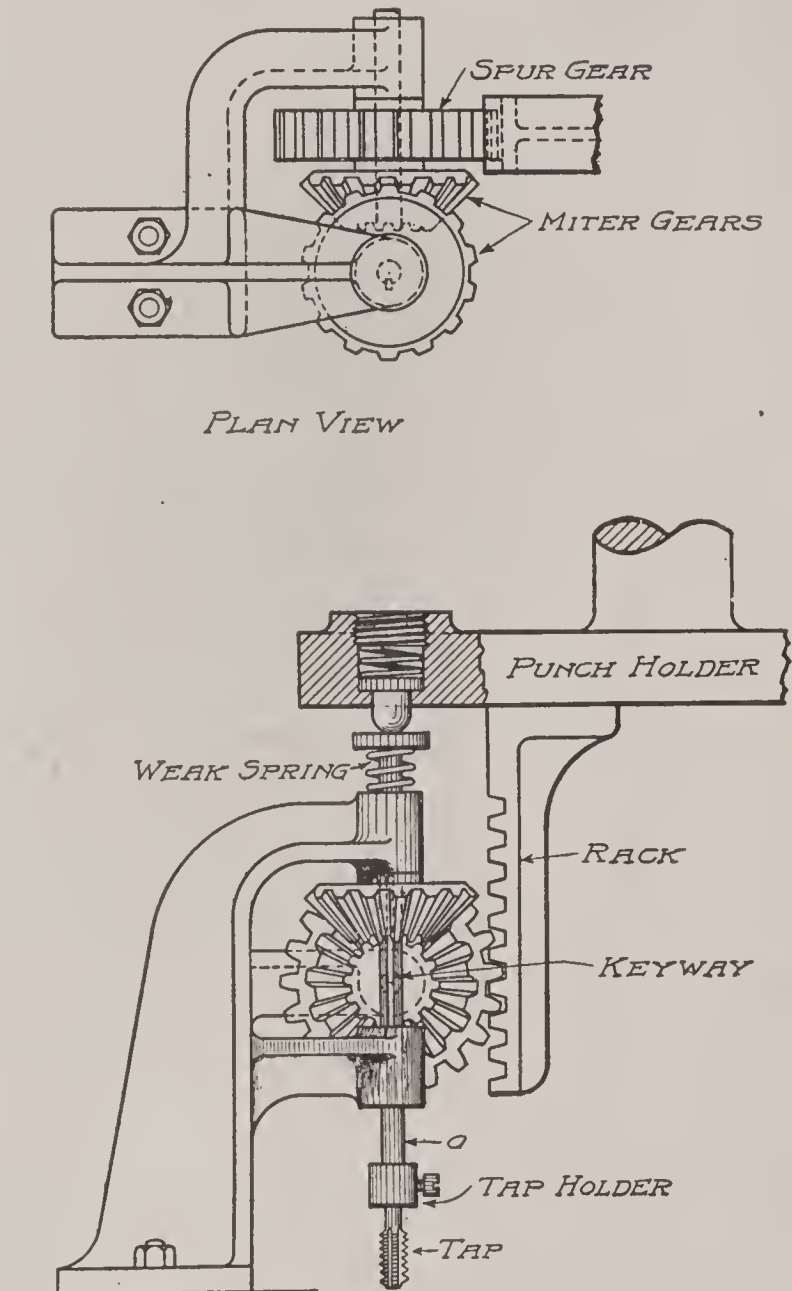


Fig. 24. Design of Tapping Fixture for Tapping Hole in Blank

## DRAWING AND FORMING

**Simple Drawing Die.** Any type of die that performs a drawing operation is referred to as a drawing die, regardless of its construction. Fig. 25 shows a drawing punch and die in its simplest form, producing only shallow cups, as in Fig. 26, from blanks made from another die. The chief difference between this punch and die and the plain blanking type is that the punch, instead of fitting the die, is made smaller than the die by an amount equal to twice the thickness of the stock to be drawn. Also the sharp corners of the die

are removed to allow the stock to slide freely from the flat state to cup shape, and to prevent scratching the blank.

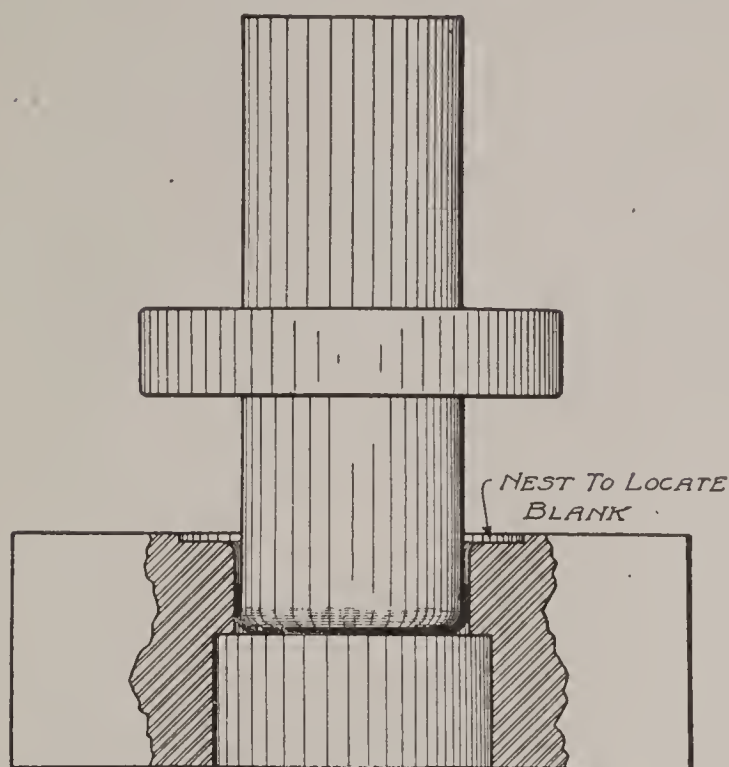


Fig. 25. Simple Form of Drawing Punch and Die

Fig. 27 shows types of cups that are formed by the drawing die in Fig. 28. When using this design of die, however, the blanks must be punched out with another die. This die should not be designed for use except when a small quantity of cups are required.

For producing the blanks seen in Fig. 29, the type of drawing die shown in its simplest form in Fig. 30 is employed. This die also

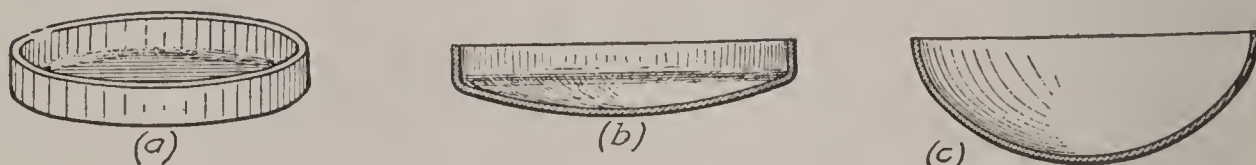


Fig. 26. Typical Cups Formed by Drawing Die

requires blanks previously punched from sheet stock. As is the case with all the foregoing drawing dies, this type should not be designed where rapid production or quality is required.

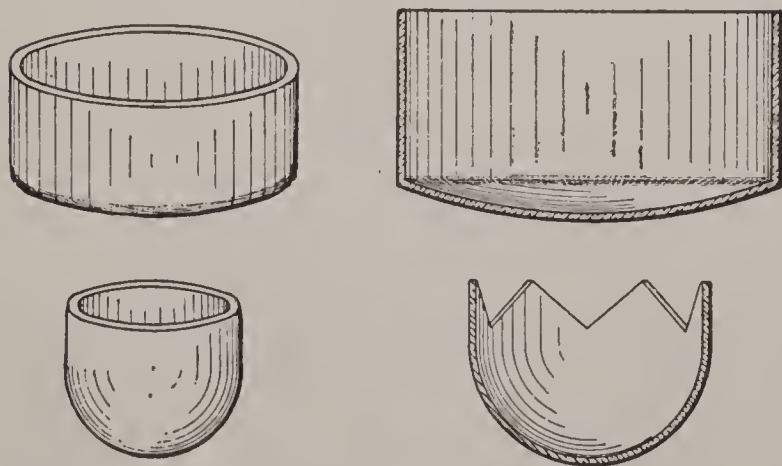


Fig. 27. Types of Cups Formed by Drawing Die, Fig. 28

**Blanking = and = Drawing Die.** We now come to that class of tools known as blanking- and -drawing dies. The designer is limited somewhat in his selection of a type of die that is best suited for the

work, as he must design the dies that will be operative in the presses at hand. The die shown in Fig. 31 is designed for use in what is

termed a single-action press, such as that in Fig. 32. In this case the press has only one crank on the drive shaft, and to that crank is attached the driving rod which actuates the ram, so that the ram

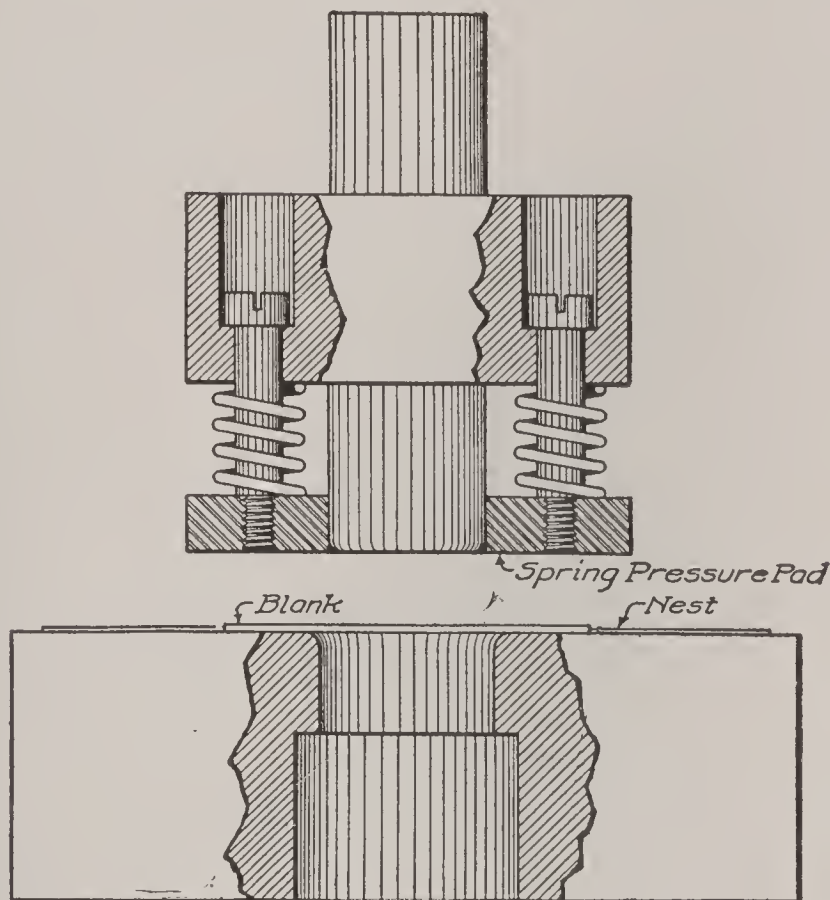


Fig. 28. Drawing Die with Spring Stripper

has but one action. The die, Fig. 31, produces any of the cups shown in Figs. 26, 27, and 29, and has the advantages over any

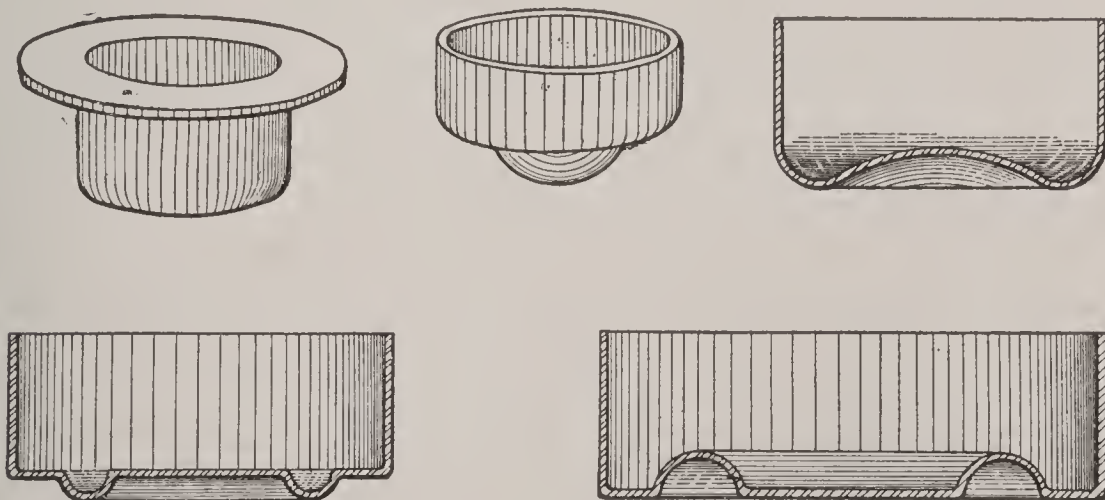


Fig. 29. Typical Blanks Produced by Drawing Die, Fig. 30

drawing die thus far shown of punching out its own blank and of drawing the blank to a cup at each stroke of the press. It will be noted that the die is somewhat complicated and that the blanking

punch is also the drawing die. This type of die should be designed for rapid production only when compelled to use a single-action punch press.

*Operation.* In operation, the blanking punch  $d$  cuts out the blank and the blank is pinched between the angular faces of the lower stripper  $c$  and the blanking punch. As the punch continues to descend, the lower stripper descends also and the forming punch

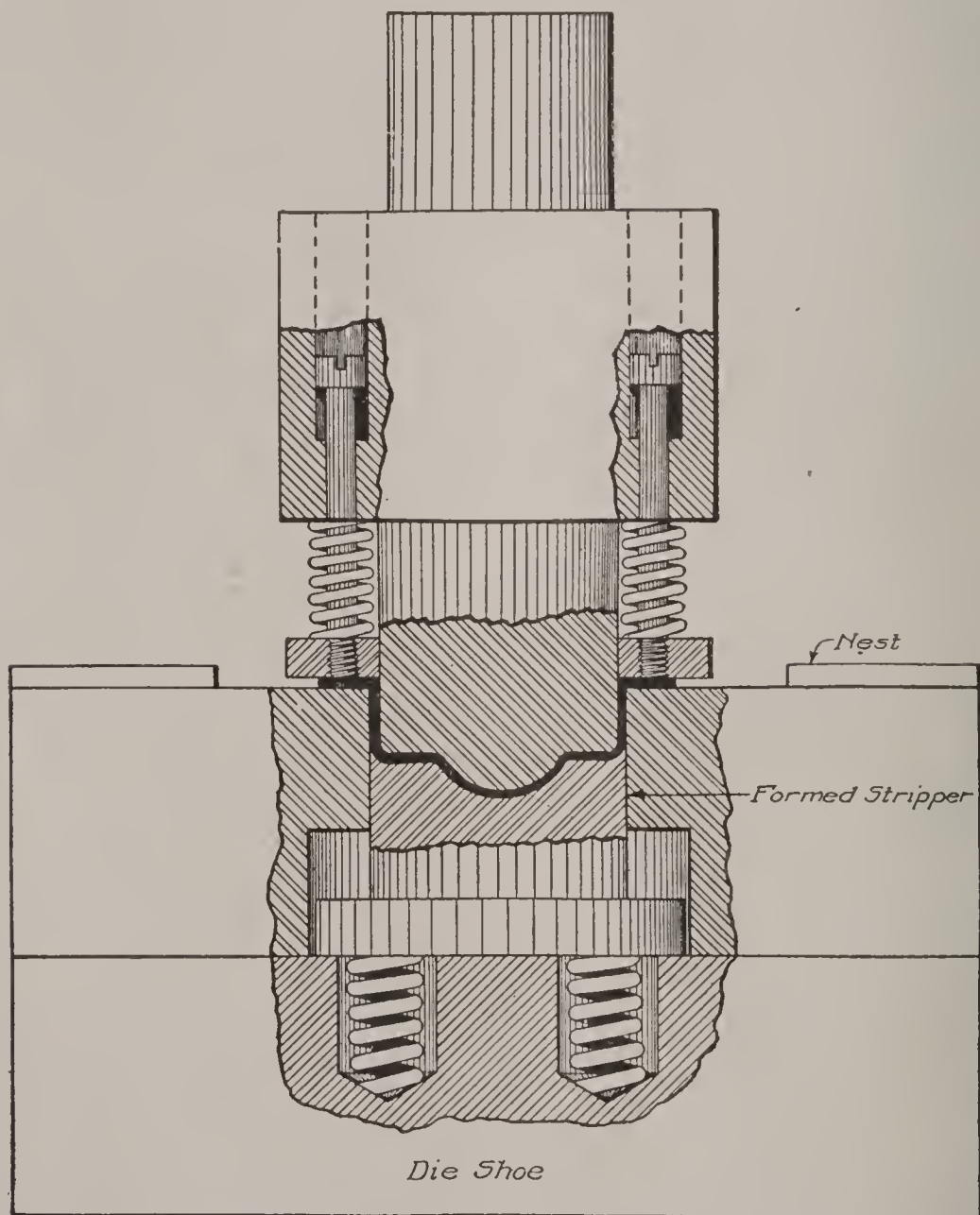


Fig. 30. Another Form of Drawing Die

$e$  forces the blank up into the drawing die, which is the recess  $f$  in  $d$ . The stroke of the ram is so adjusted that at the extreme point of the downward stroke the forming punch  $e$  presses the cup firmly against the face of the upper stripper  $a$ , while at the same time the back face of  $a$  is pressing firmly against the bottom of recess  $f$ .

As the ram ascends, the lower stripper accompanies the blanking punch, that is, the stripper  $c$ , being actuated by heavy springs  $h$ ,

ascends at the same speed as that of the blanking punch and strips the cup from the forming punch *e*. The lower stripper *c*, therefore, performs the double function of stripping the cup from the forming punch and of pressing the stock against the angular face of the blanking punch to prevent wrinkling the stock. It is obvious that if the flat blank were not held under pressure, the blank would wrinkle when it changes from a flat blank, say 6 inches in diameter, to a

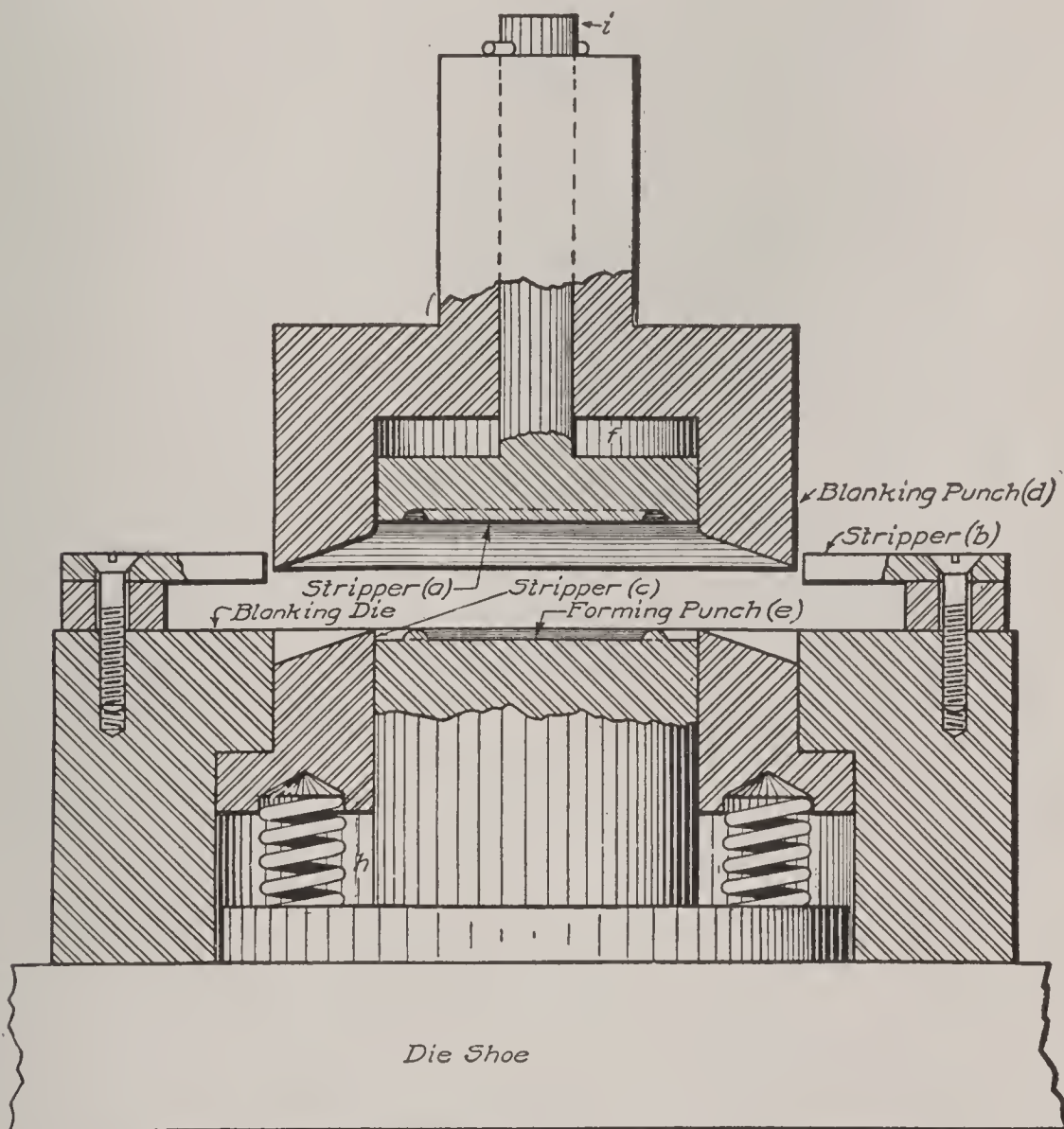


Fig. 31. Blanking-and-Drawing Dies Designed for Single-Action Press

cup shape 3 inches in diameter. The designer must employ powerful springs to prevent wrinkling. Near the end of the upward stroke of the ram, the stripper shank *i* comes in contact with a cross-rod in the press called the knock-out rod, which pushes the stripper *a* down, leaving it in the position shown in Fig. 31. This causes the finished cup to drop from the drawing die to the face of the blanking die.

The operator must remove the cup from face of the die before blanking and drawing the next one—a somewhat slower operation than when this same die is used in a press of the inclinable type such as shown in Fig. 33; the press being tilted on a decided angle, the cups cannot remain on the face of the die, thus enabling the operator to greatly increase the quantity of production. Therefore, the designer must learn which types of press he may have at his command, and when designing dies of this character he must select the die best adapted and have it fitted to the press that will insure

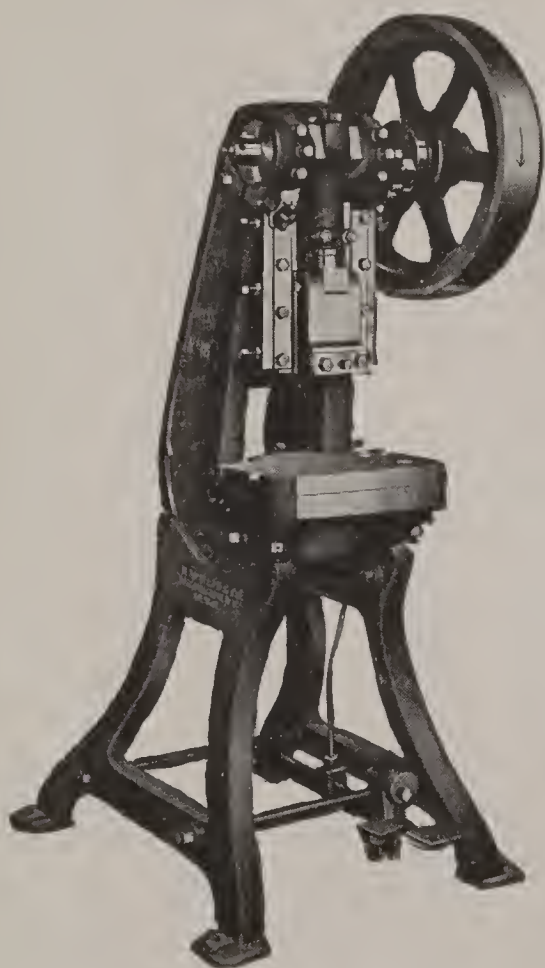


Fig. 32. Single-Action Press  
Courtesy of E. W. Bliss Company,  
New York City

the most rapid production. The designer should also see that the plans from which the tool-makers work contain notes calling for polished rounded corners on a drawing die, and for the sides of the drawing die and drawing punch to be highly polished.

*Double-Action Type.* Fig. 34 shows in section a drawing punch and die designed for a double-action press, Fig. 35, and to produce the cups shown in Fig. 27. The shape of the end of the drawing punch *a*, Fig. 34, governs the shape of the bottom of the cup. The term *double action* means that there really are two strokes to the press. The drive shaft has three cranks or eccentrics, as shown enlarged in Fig. 36. The two end cranks are connected to the large ram,

Fig. 35, to which is fastened the blanking punch *b*, Fig. 34, while the central crank is connected to the smaller ram, Fig. 35, which slides inside the large ram. The position of the cranks is such that in operation the ram containing the blanking punch descends, and, before the blanking punch touches the stock to be punched, the inner ram containing the drawing punch *a*, Fig. 34, starts to descend. The rams are so adjusted that just as the blanking punch reaches its lowest point, which should be when the blank is firmly pressed against the face of the drawing die *c*, the drawing

punch continues downward and pushes the blank down through the die.

For producing the cups shown in Fig. 27, the die in Fig. 34 is the ideal one, due to its simplicity and speed of operation, for the

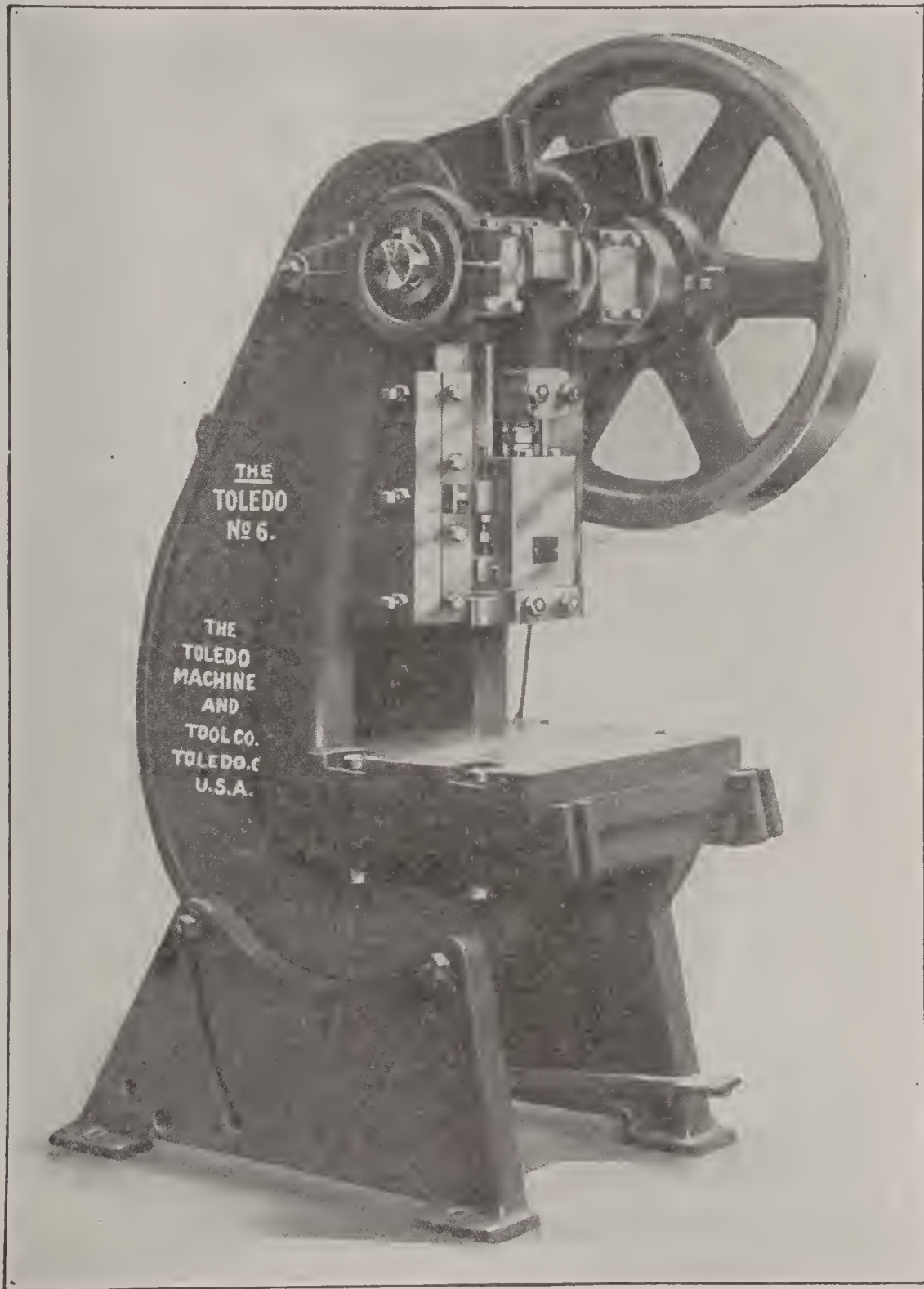


Fig. 33. Inclined Single-Action Press  
*Courtesy of Toledo Machine and Tool Company, Toledo, Ohio*

blanks are pushed clear through the die. The double-action type of die, however, is not any better suited for those cups in Fig. 29 than the die for a single-action press shown at Fig. 31, for in using either

type the cups would have to be removed from the top of the die unless the press were inclinable.

**Deep Drawing Die.** The term deep drawing is applied to dies that are employed to produce long shells or deep cups, such as that in Fig. 37. These dies might properly be classed as redrawing dies. It is obvious that the shell in Fig. 37 could not be produced in a

drawing die in one operation, for the diameter of the drawing punch would be so small relative to the draw that the punch would push through the blank. In other words, the pressure required to transform the large blank into a long slender tube, at one stroke, is greater than the pressure required to push the punch through the stock.

To produce the shell in Fig. 37, there is required a series of redrawing dies such as that in Fig. 38, and as can best be understood by referring to the successive drawing operations indicated in Fig. 39. When a cup has passed through several redrawing operations, the stock in the cup becomes very hard and the cups must be an-

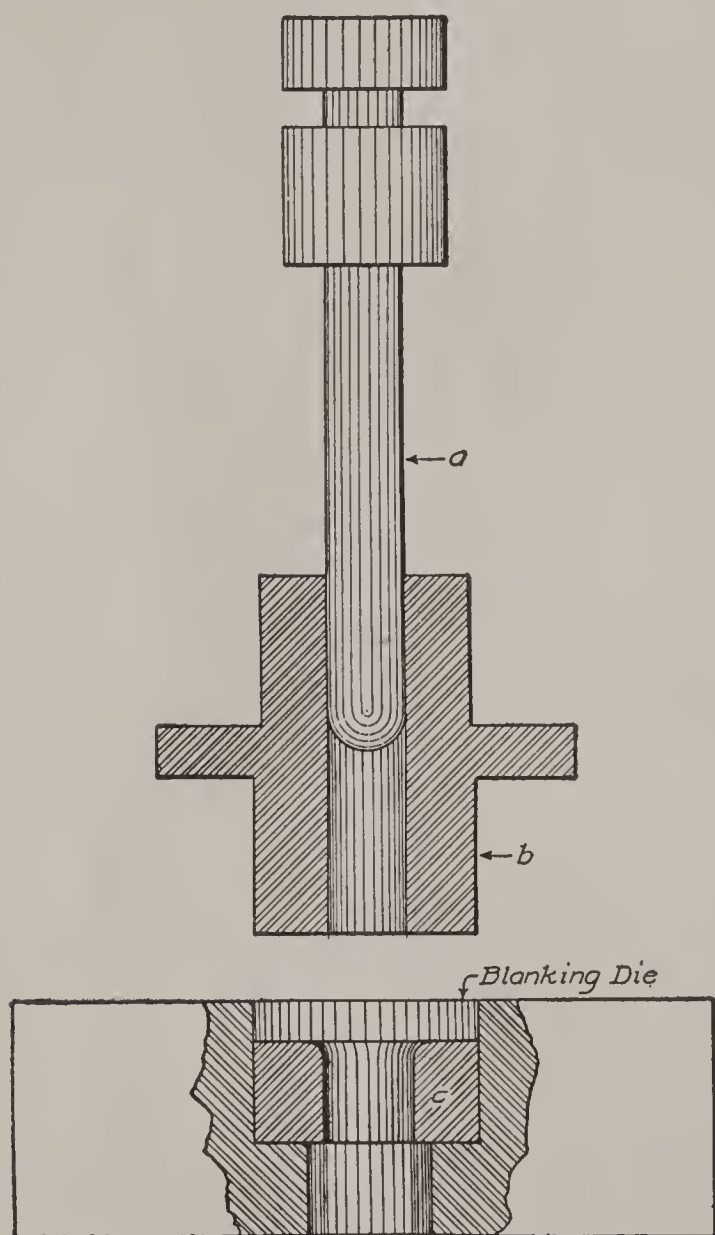


Fig. 34. Drawing Punch and Die Designed for Double-Action Press

nealed before further drawing. The cup in Fig. 39 would require possibly two annealing operations—the deeper the cup, the greater the number of draws and annealing operations. The dies should be designed for the successive operations in practically the shapes shown by the dotted lines in Fig. 39, and, as in Fig. 40, should be provided with a plunger actuated by a powerful spring, to insure the cup being forced from the die, and also with a close fitting stripper surrounding the punch, care being exercised

that the stripper for the punch is high enough from the face of the die to allow the blank to be readily removed from the die.

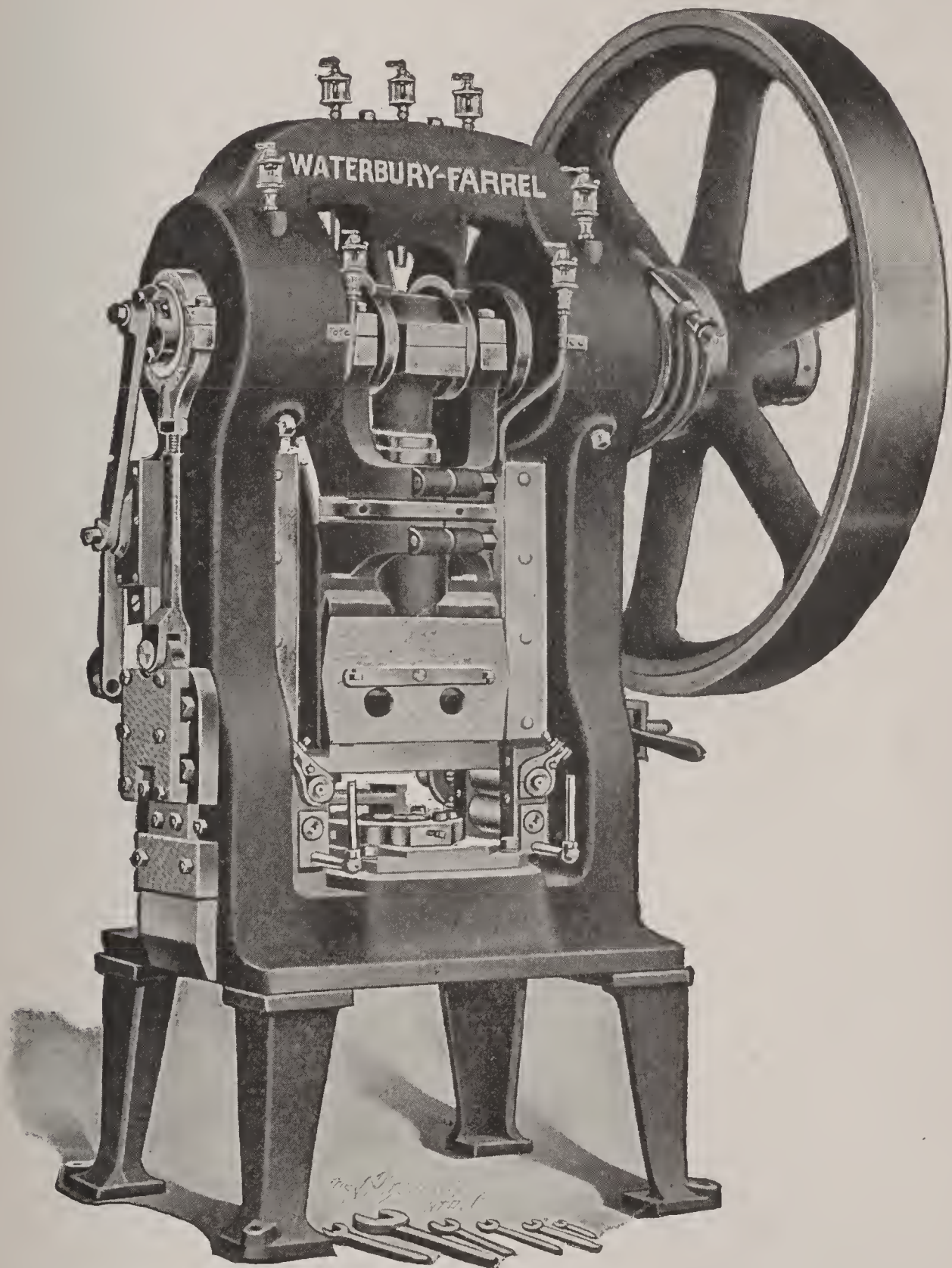


Fig. 35. Double-Action Press

*Courtesy of Waterbury-Farrel Foundry and Machine Company, Waterbury, Connecticut*

**Shaving Die.** When a punch passes through the strip of stock to be punched, the blank punched out is really broken from the stock, rather than being cut apart, and this breaking leaves a ragged edge on the blank and in the hole in the stock. The thicker the stock,

the more pronounced this ragged edge is. Blanks punched from, say,  $\frac{1}{4}$ -inch sheet stock are decidedly tapering, as in Fig. 41. When

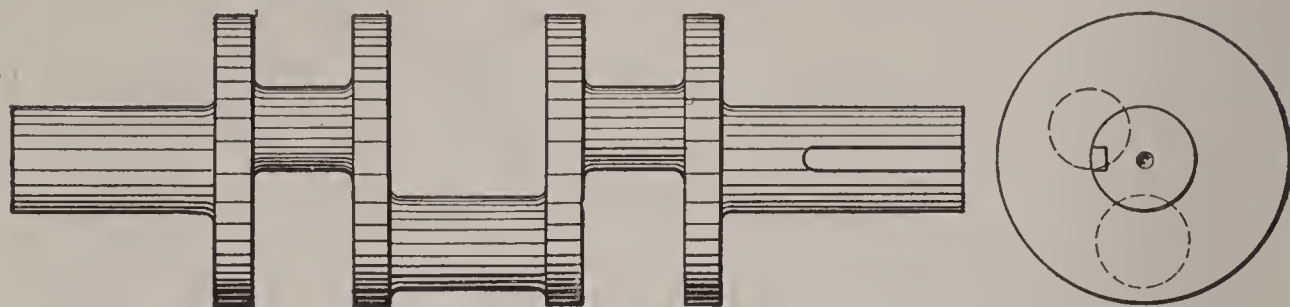


Fig. 36. Crank Shaft of Double-Action Press

punching cams, levers, eccentrics, or small parts for typewriters, adding machines, cash registers, etc., where the action of the cams and levers must be smooth, a shaving die, shown in its simplest form in Fig. 42, is employed for finishing the blank. The blanking die is designed to punch the blank very close to the desired

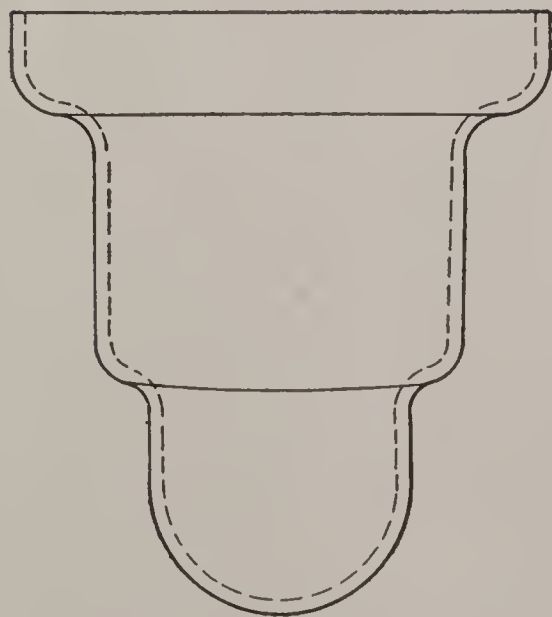


Fig. 37. Typical Deep Drawing Blank

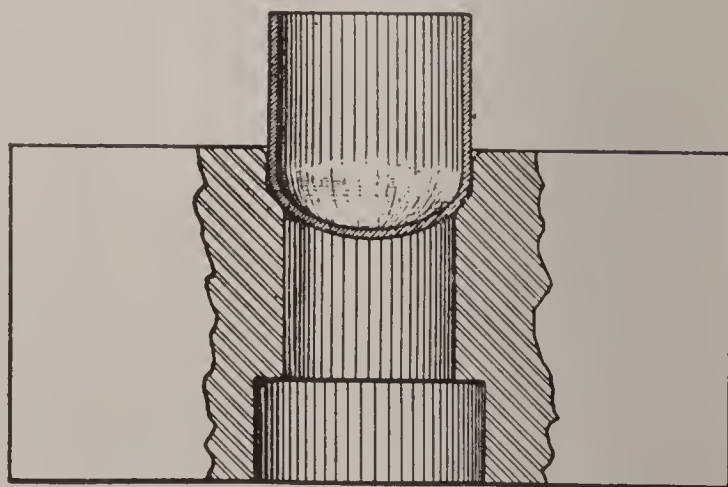
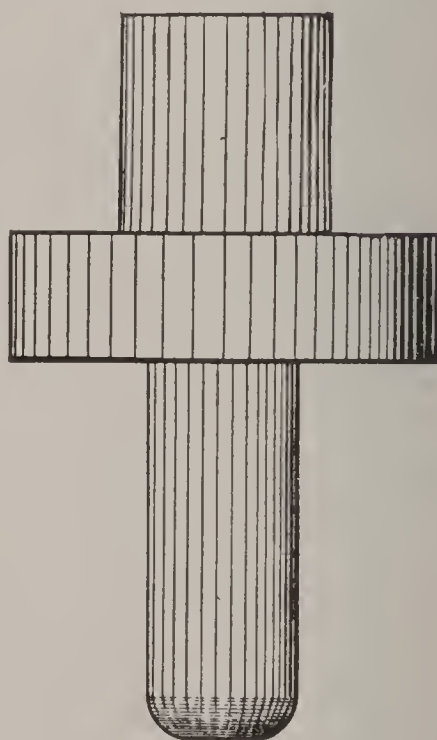


Fig. 38. Series of Redrawing Dies for Deep Drawing Work

size or shape, leaving an allowance of only a few thousandths for shaving. In connection with such a piece as the eccentric washer, Fig. 43, the outer edge of which must be smooth, as it runs in a

bearing, the designer should employ the subpress die, Fig. 21, because this type of die produces the most uniform blanks.

As a rule, the shaving die is not given clearance, as is the case with blanking dies, and, as the punch must fit the die very closely, it is the general practice to make the shaving die in accordance

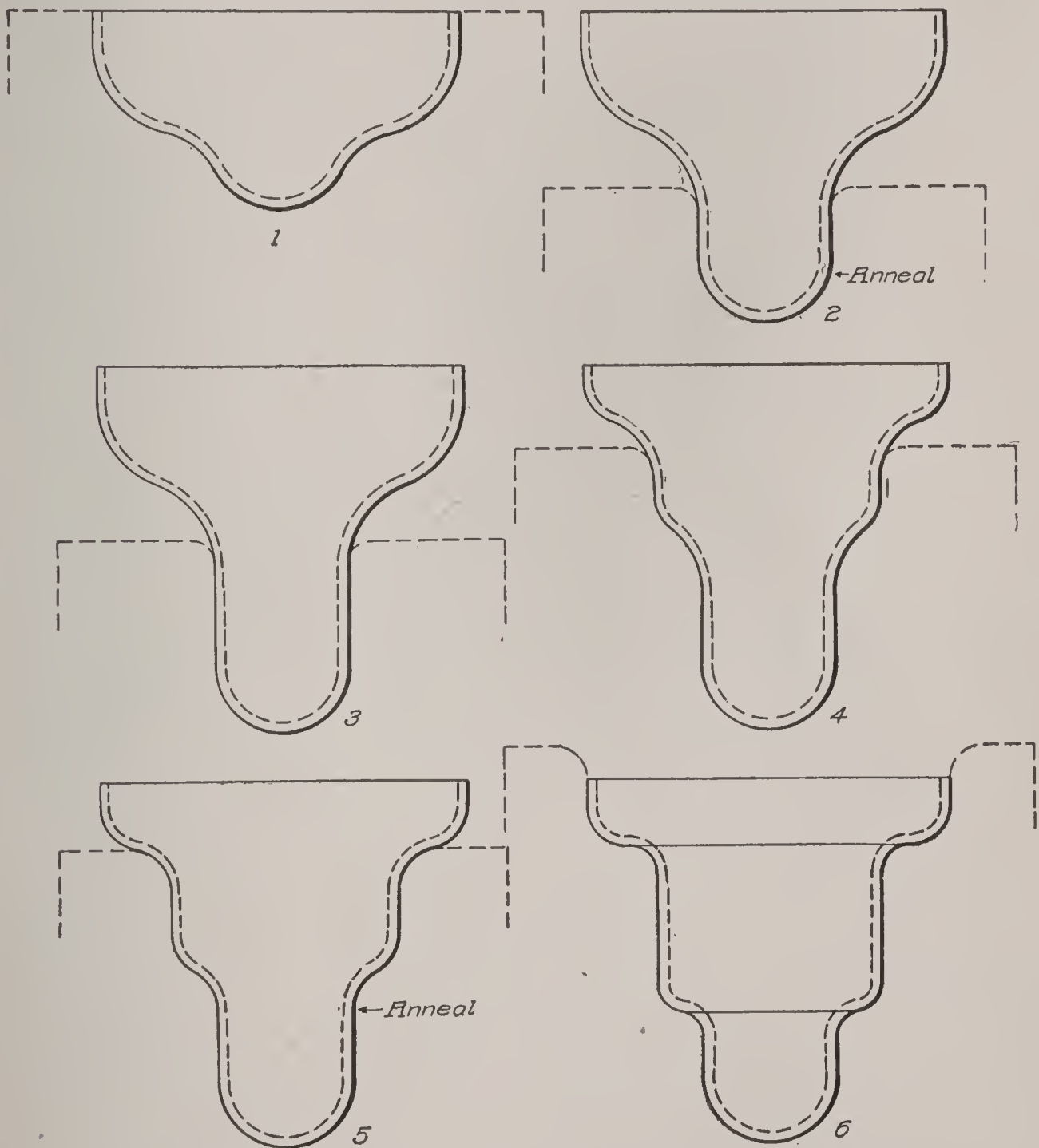


Fig. 39. Six Stages in Process of Forming Deep Drawn Shell, Fig. 37

with subpress construction, which insures alignment of punch and die. The shaving die can be fitted with a close fitting spring stripper, as in Fig. 42, or the blanks can be pushed through, as desired. By making the die, say, 1 inch deep, and without clearance, and by keeping the die and blanks well lubricated, and pushing the blanks

clear through, a highly polished edge is produced on the blank. The designer should bear the shaving die in mind and use it wherever feasible, for it is a very rapid method of producing pieces of uniform size.

**Embossing Die.** Fig. 44 shows samples of ordinary embossing—though for heavy embossing, as at *a*, Fig. 44, a drop press is best

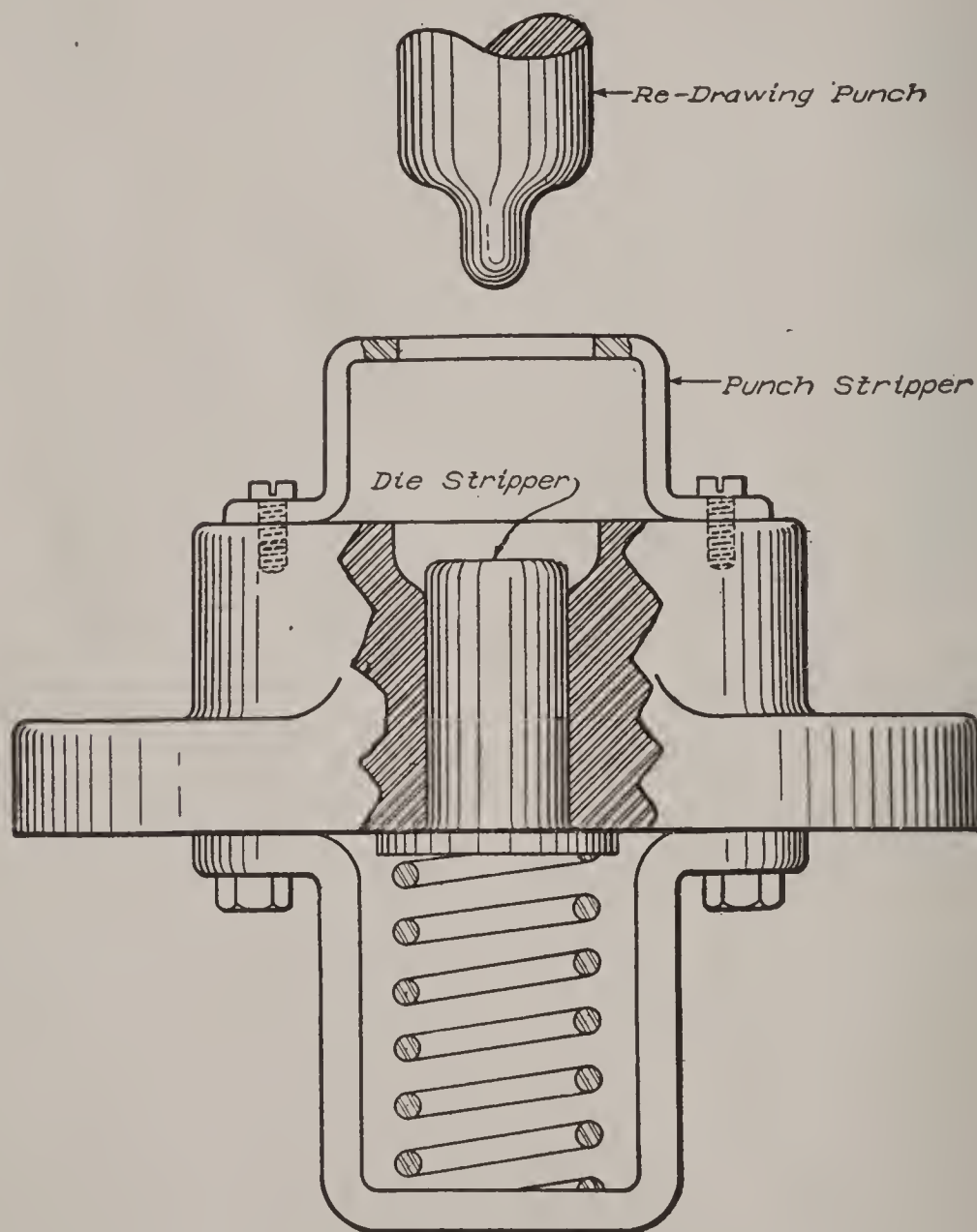


Fig. 40. Punch and Die for Producing No. 2, Fig. 39

suited. If the embossing desired is somewhat heavy and there is danger of springing the shaft of the punch press, and the designer must of necessity use a punch press, it is better to use a die of design such as that in Fig. 45, rather than to have the blow struck directly.

**Extruding Die.** If a cartridge shell were filled with butter, and a lead pencil forced to the bottom of the shell, the butter would ooze or flow up the pencil. This holds true with metal; it is simply

a matter of pressure. Small eyelets, hollow rivets, and thin tubes are economically made with extruding dies, such as in Figs. 46 and 47. In operation, referring to Fig. 47, a punched washer of predetermined thickness is dropped into the recess of the die, and as the punch fits the recess there is only one path for the metal to flow in, and it is then simply a question of pressure. As it requires time for the metal to flow, the press must travel comparatively slow, and therefore hydraulic presses are used. If an extruding die were fitted to a punch press running at ordinary speed for blanking—about 100 revolutions per minute—it would be apt to break the shaft of the press, as there would be practically a direct blow. Another type of extruded work is shown at *a*, Fig. 46. This scheme is often employed where a tapped hole is desired in thin stock, as at *b* in the same figure.

**Forming Die.** Fig. 48 shows a forming die in its simplest form. Forming dies can be made part of many dies that pierce and cut off, or, if the blank has straight sides as at *a*, Fig. 49, the stock can be purchased in the proper width, and by adding the forming die

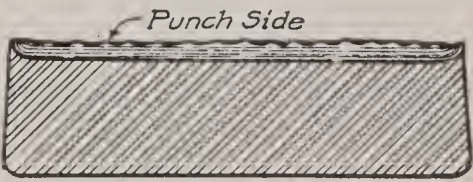


Fig. 41. Blank Punched from Quarter-Inch Stock Showing Tapering Sides

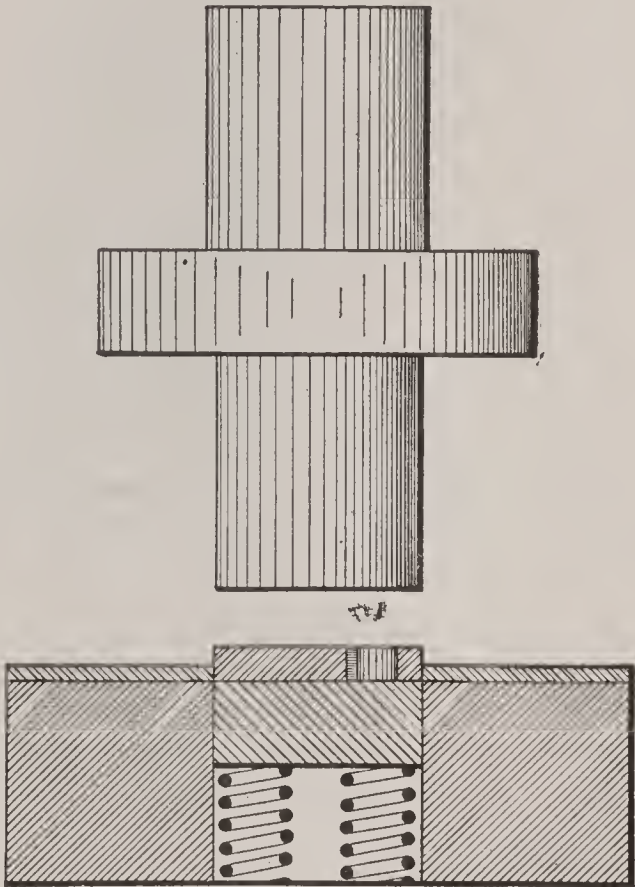


Fig. 42. Shaving Die

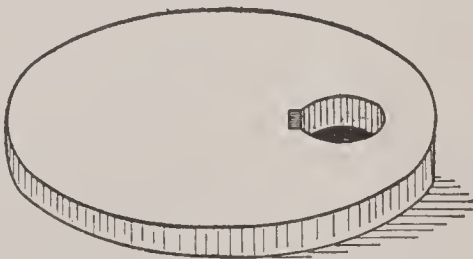


Fig. 43. Blank for Eccentric Washer

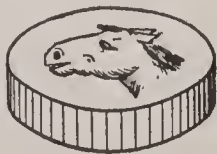
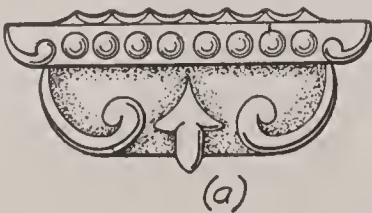
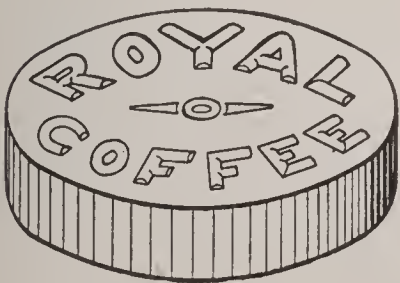


Fig. 44. Typical Examples of Embossing

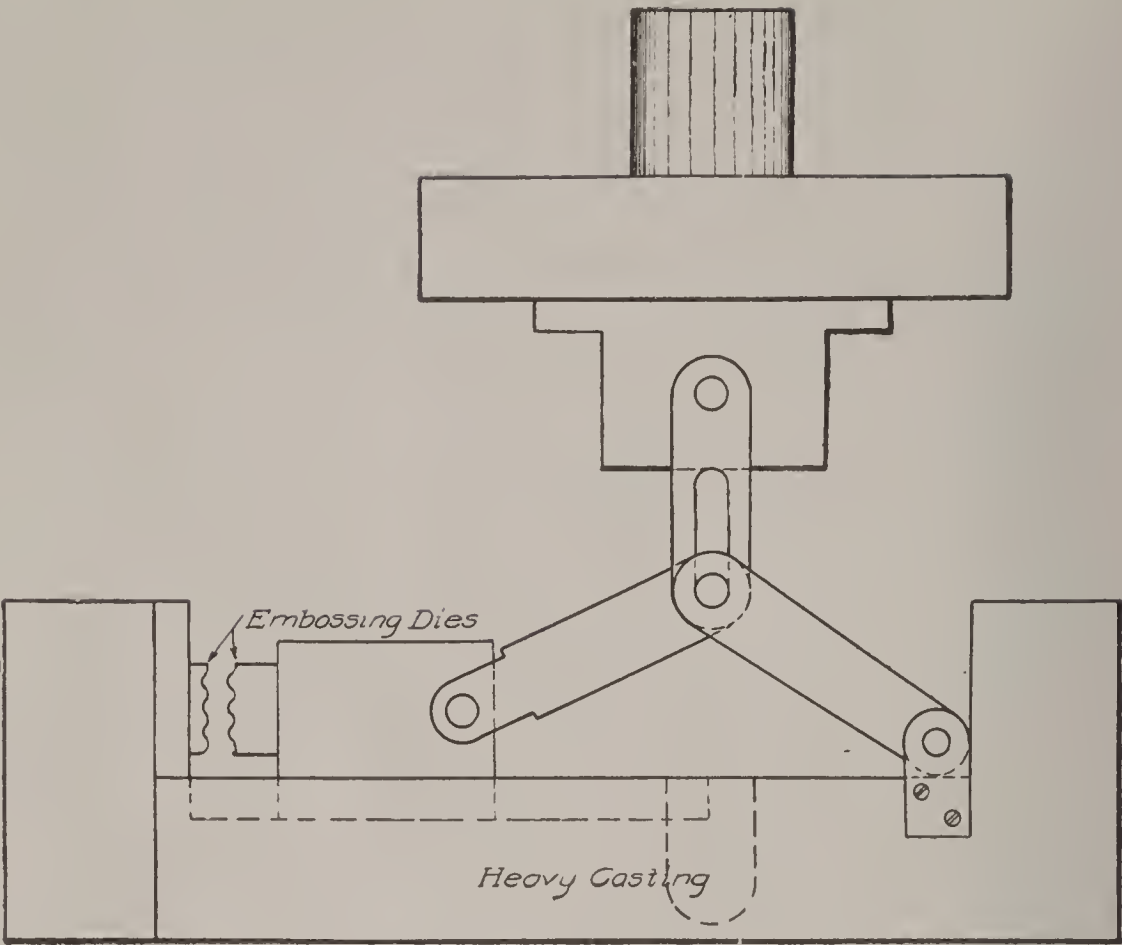


Fig. 45. Embossing Press and Die

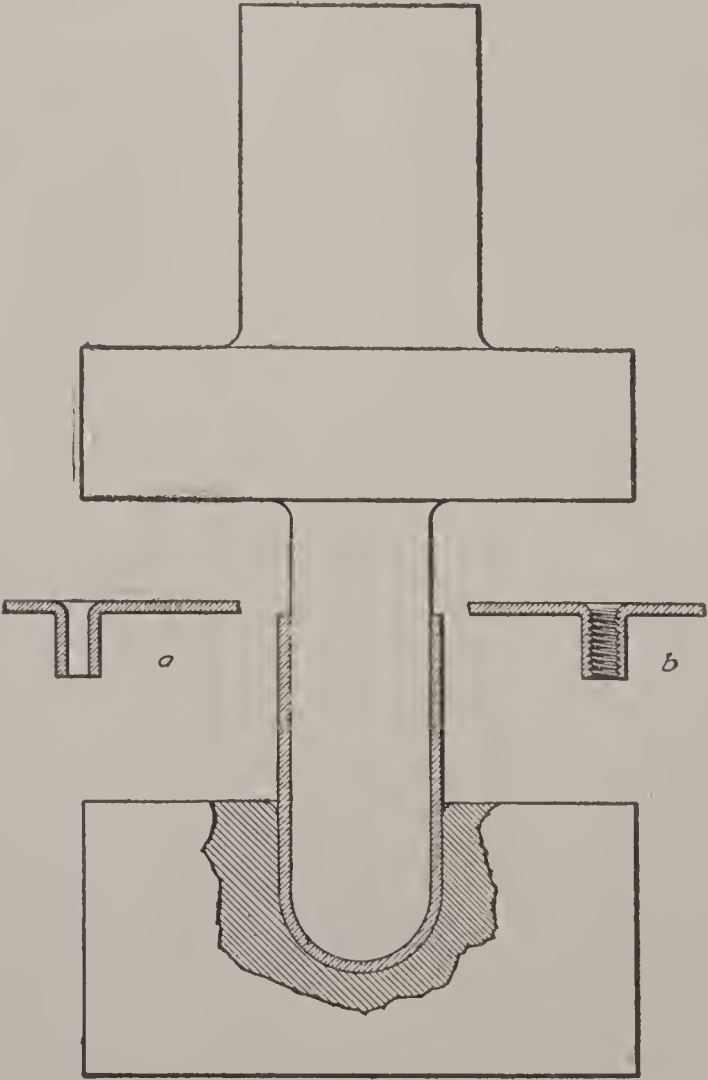


Fig. 46. Typical Extruding Die

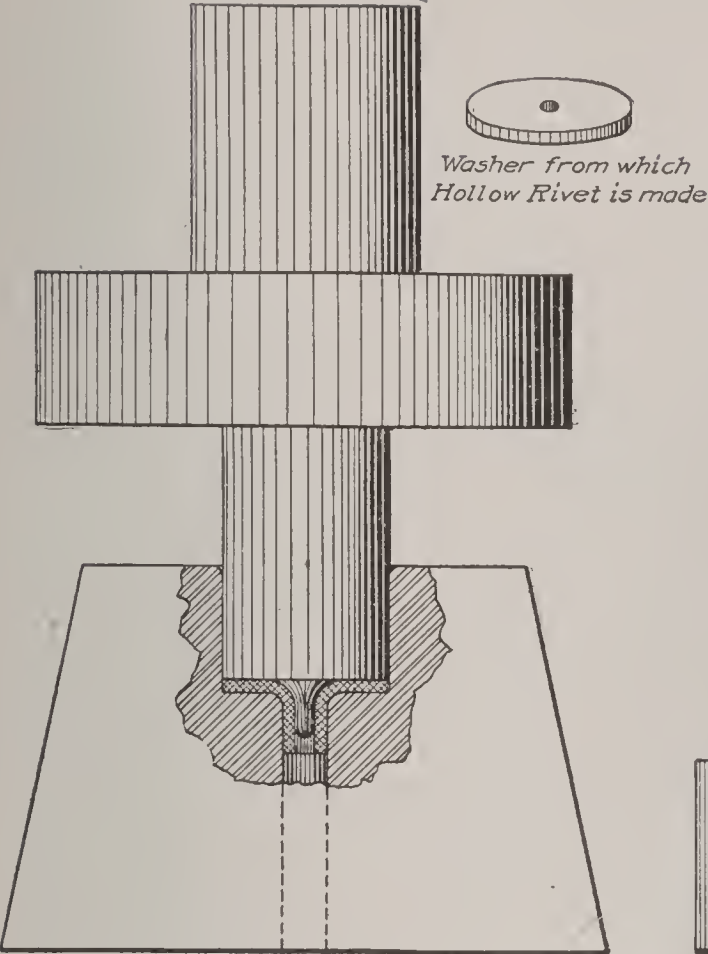


Fig. 47. Operation of Extruding Dies

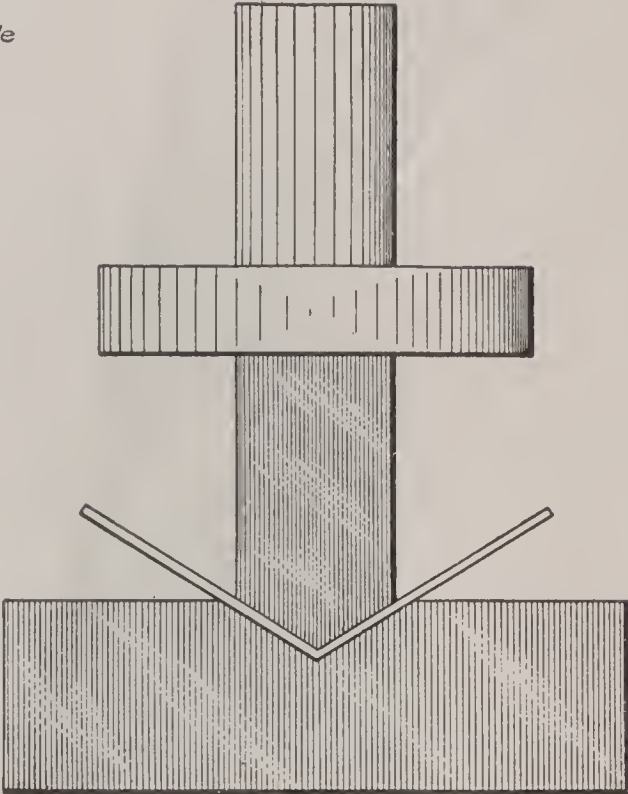


Fig. 48. Simple Forming Dies

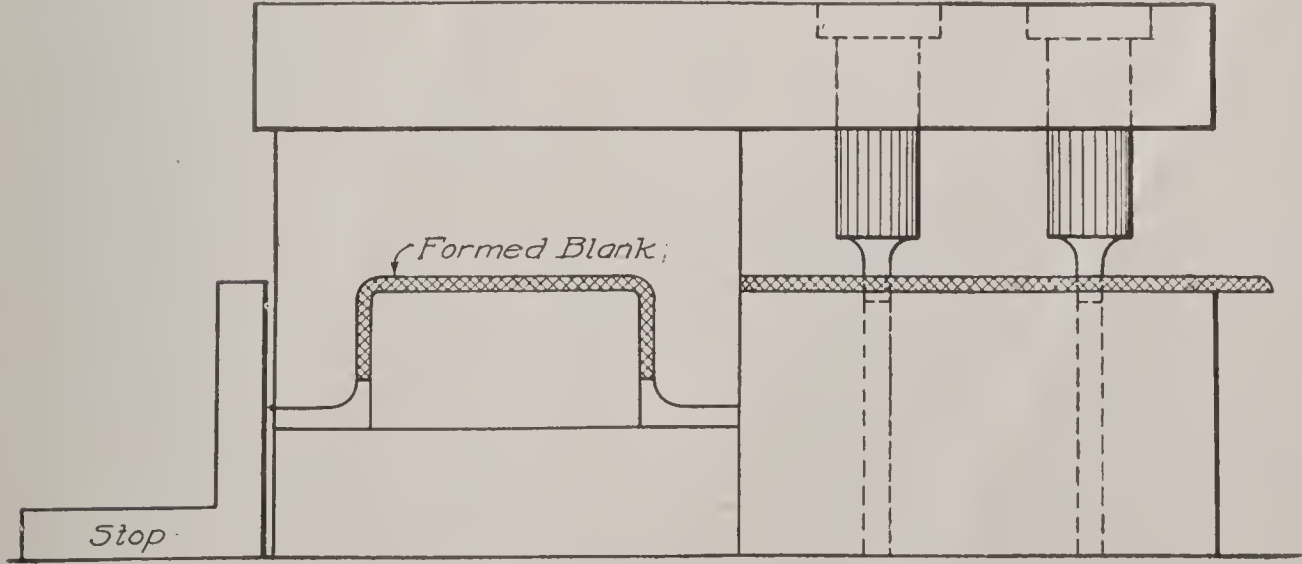
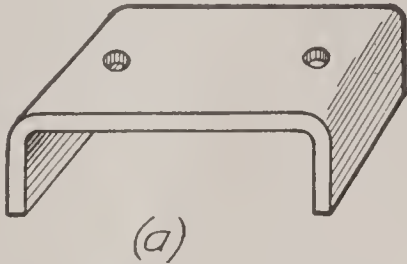


Fig. 49. Piercing and Forming Die Work

to the end of the piercing-and-blanking die, as shown in Fig. 49, the blank can be pierced, cut off, and formed. The designer should always bear in mind that the forming points in a punch and die may

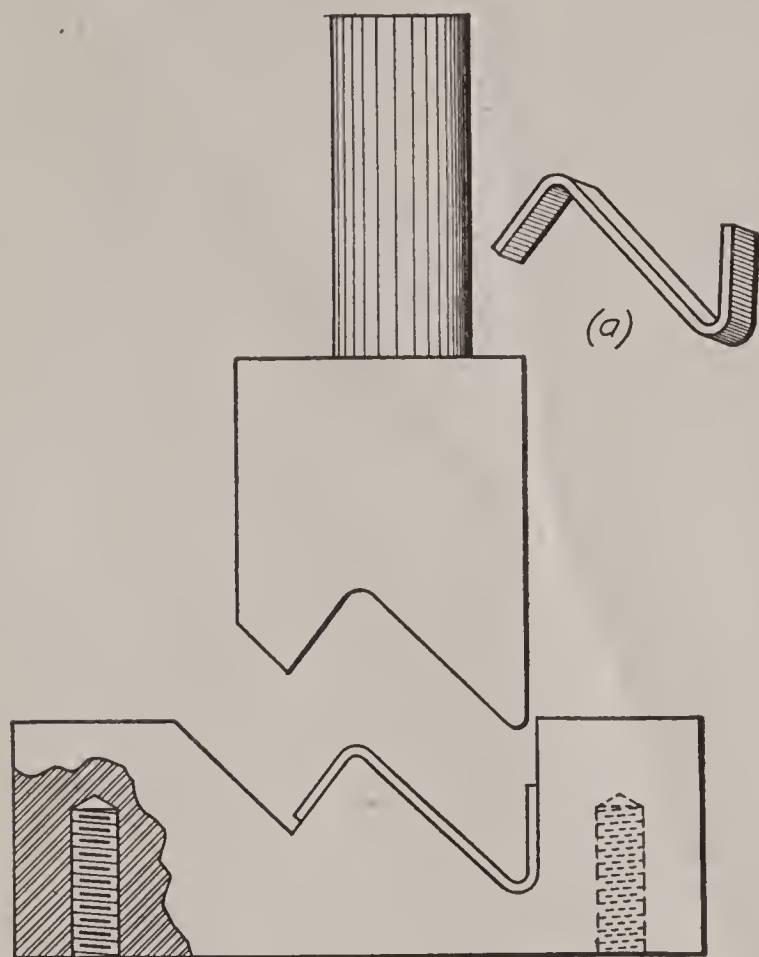


Fig. 50. Typical Forming Die and Blank

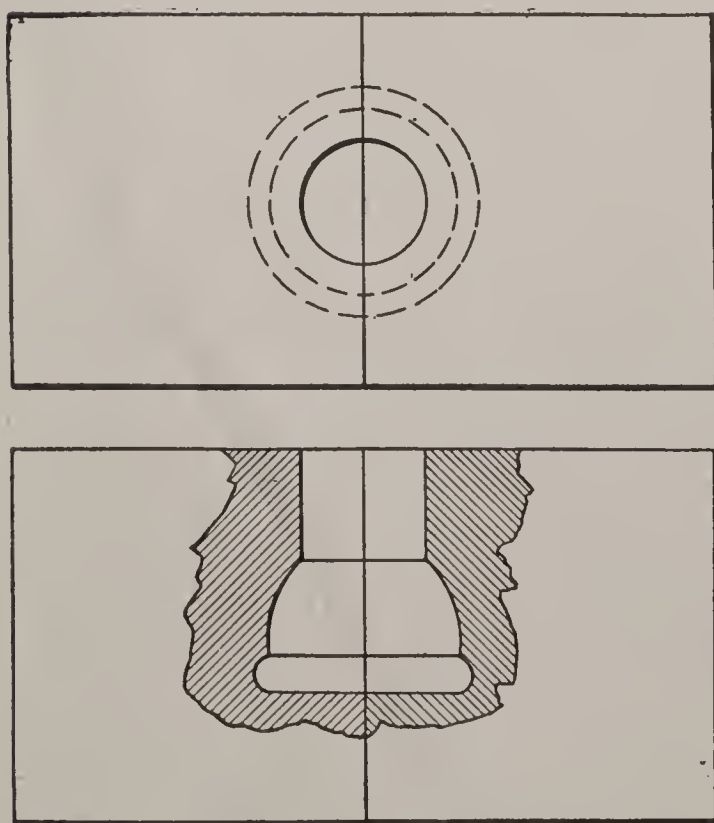


Fig. 51. Design for Water Forming Die

be changed from the position shown in Fig. 48, and that formed pieces, such as at *a*, Fig. 50, can be easily made in one stroke.

*Liquid Forming.* Fig. 51 shows a plain design of water forming die. The designer can elaborate upon this design and produce intricate forms, using water. The dies are designed in halves, one-half stationary, while the other half slides, being actuated by a lever that can be locked when the halves are firmly pressed together. In operation a drawn cup such as *a*, Fig. 52, is filled with water, the cup is inserted in the die and the halves of the die are closed and locked. The punch, which is attached to a drop hammer, fits the inside of the cup closely, and, as the hammer falls, the punch strikes the water, forcing the metal into all parts of the die. The object in making the dies in halves is to allow removing the blanks when they are formed to a larger diameter as in *b*, Fig. 52.

This same design of die can be used for thin stock when a spring rubber plug is employed. The rubber forces the thin metal walls

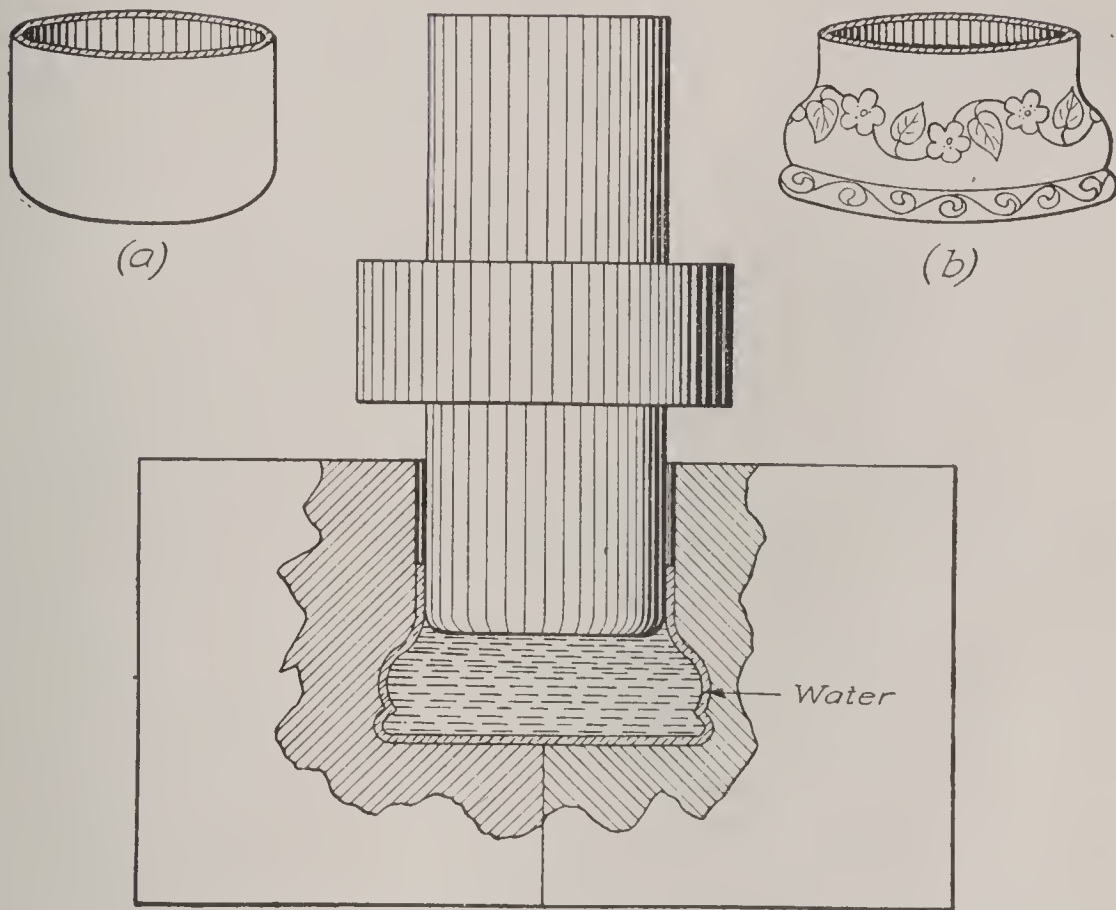


Fig. 52. Water Forming Die and Formed Blank

of the cup to all parts of the die, and as rubber assumes its original shape after pressure is released, it can be easily removed and used over and over.

## JIGS AND FIXTURES

**Purposes.** The term *jig* is applied to a device designed to hold work while being machined, and to contain guides to govern the cutting tools. Jigs are divided into many classes, such as grinding, boring, turning, planing, milling, and drilling jigs.

**Drilling Fixtures.** Extremely accurate work cannot be obtained in jigs for drilling because there must be a difference between the diameters of the bushing hole and the drill to be used, and this difference can be transferred to the work. In *a*, Fig. 53, is shown a drilling jig in its simplest form.

The aim of the designer should be to design the jigs as nearly foolproof as possible, for in the use of jigs there must be locating points to position the work and locking devices for holding the work

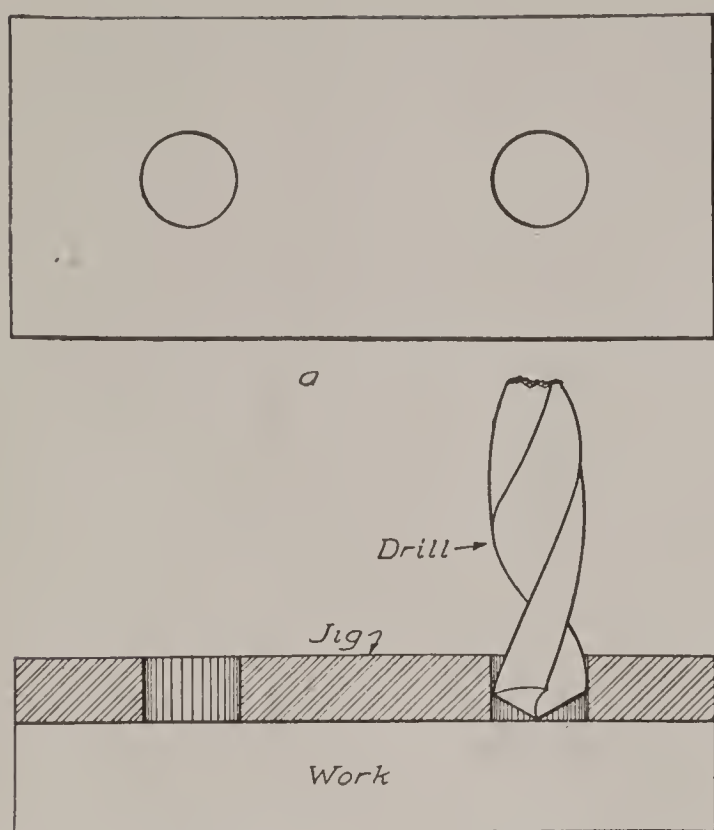


Fig. 53. Simple Form of Drilling Jig

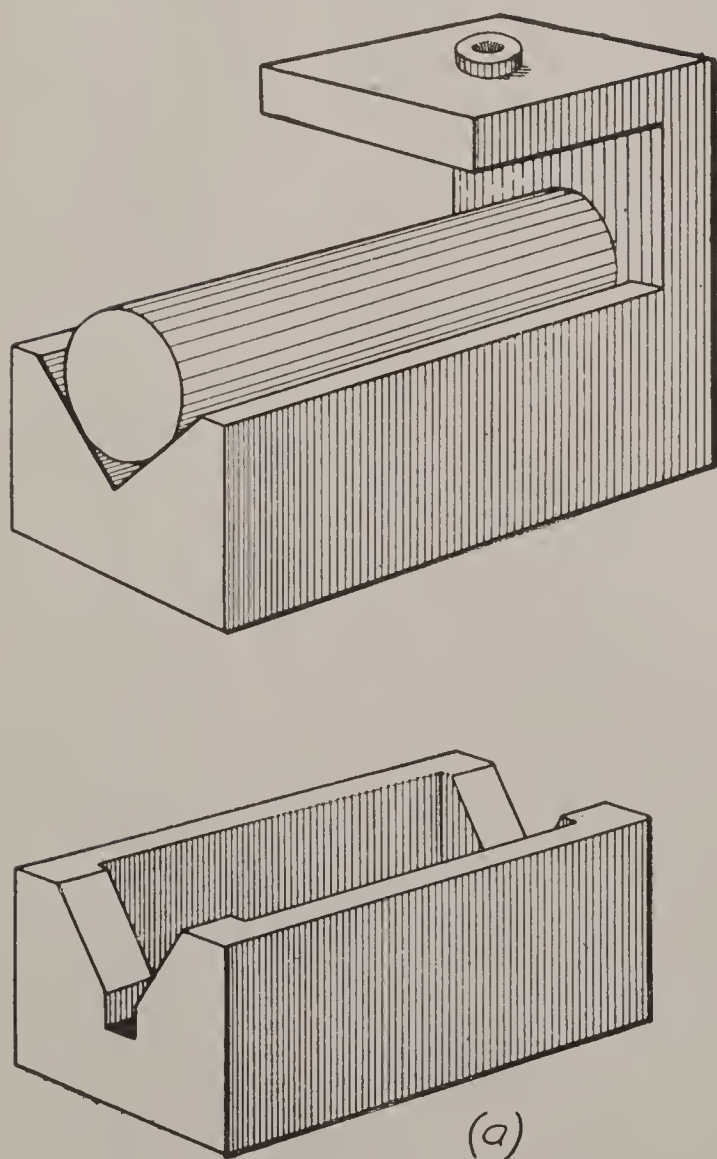


Fig. 54. Drilling Jig with V-Rest for Centering Work

in position. Should a jig be made where the successful duplication of work is left partly dependent upon the care of an unskilled operator, there is the possibility of many ruined pieces, due to the operator's failure through lack of interest to properly clean the locating points, to remove chips from corners, or to properly secure the work in the jig. Therefore, all jigs should be designed in such a manner that the personal element is reduced to the minimum.

*V-Type Jig.* The feature of the simple design of jig in Fig. 54 is the V-shaped portion for centrally locating a round piece of work. When a lubricant is used in the machining operation the chips stick to the angular sides, but to reduce this danger to the minimum, the V is relieved, as at *a*, Fig. 54. In Fig. 55 we have the same V feature but of improved design intended to mechanically locate and hold. It is noted that there are no locking screws, cams, or adjusting screws for the operator to forget, and that all that is necessary is for the operator to insert the piece of work

and to close the cover. This, in its simplest form, is what is known as foolproof, and the designer must design the tool at hand to operate mechanically as nearly as possible.

*Spring-Pump Locator.* Another element which enters into the design of a jig and which calls for ingenuity on the designer's

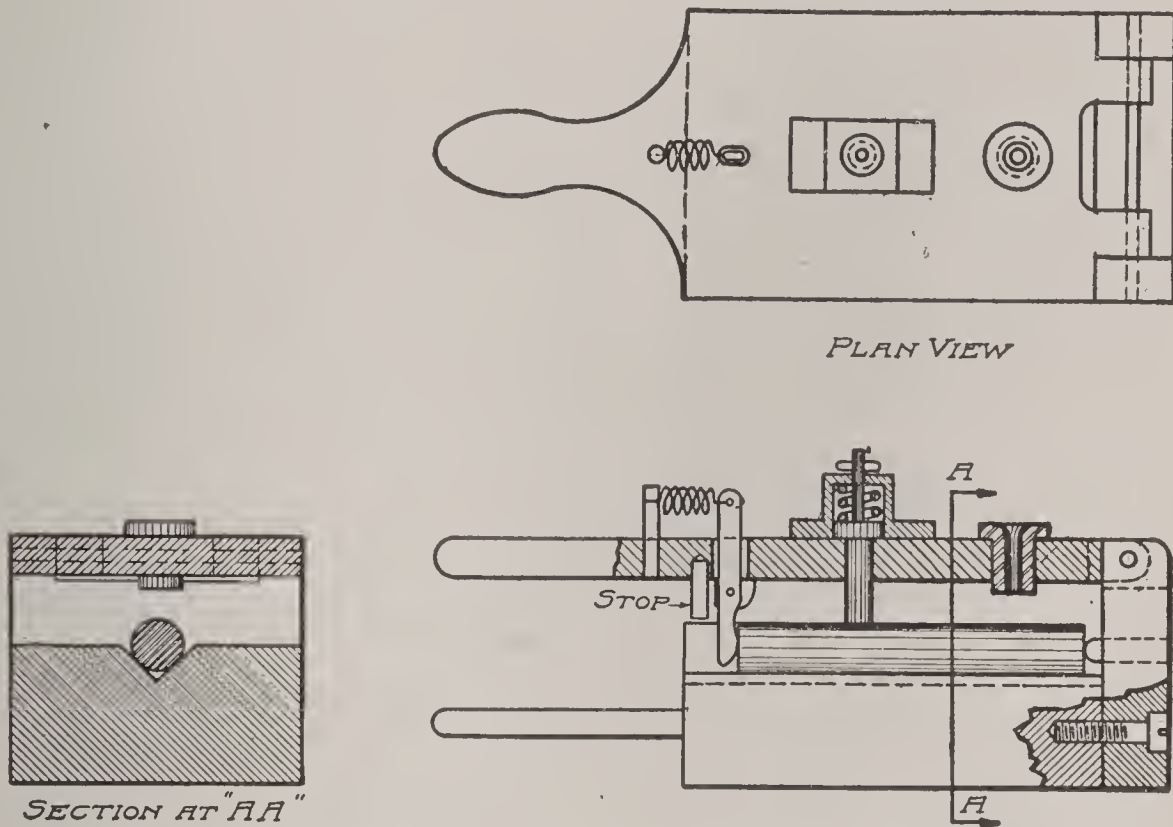


Fig. 55. Drilling Jig with V-Rest and Clamping Device

part, is the initial locating of a casting that is to be drilled, milled, or otherwise machined. Castings vary greatly, and the design of locator shown in Fig. 56, and termed a *spring pump*, is excellently adapted to centrally locate pieces of work that vary. In Fig. 57,

at *a*, is shown the end view of a carburetor body in the rough casting, while *b* shows the holes drilled, using the jig in Fig. 58, which embodies the spring-pump locators of Fig. 56. It is obvious

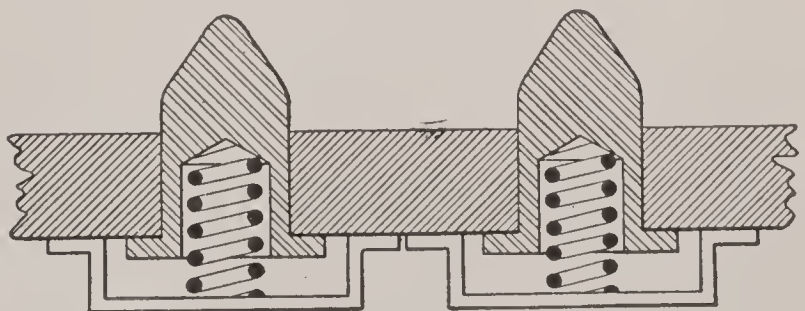


Fig. 56. Spring-Pump Locator

that burrs, unequal shrinkage, and other foundry causes, may produce such variation in castings that a positive nest, as in Fig. 59, is out of the question. In other words, if the nest were made to accommodate or fit the largest variation in the

castings, there would be such a loose fit on a smaller casting that it could turn in the nest and would look like Fig. 60 after the holes were drilled.

**Proper Relation of Operations.** Here is where the designer must be sure that the tools are designed in such a manner that the

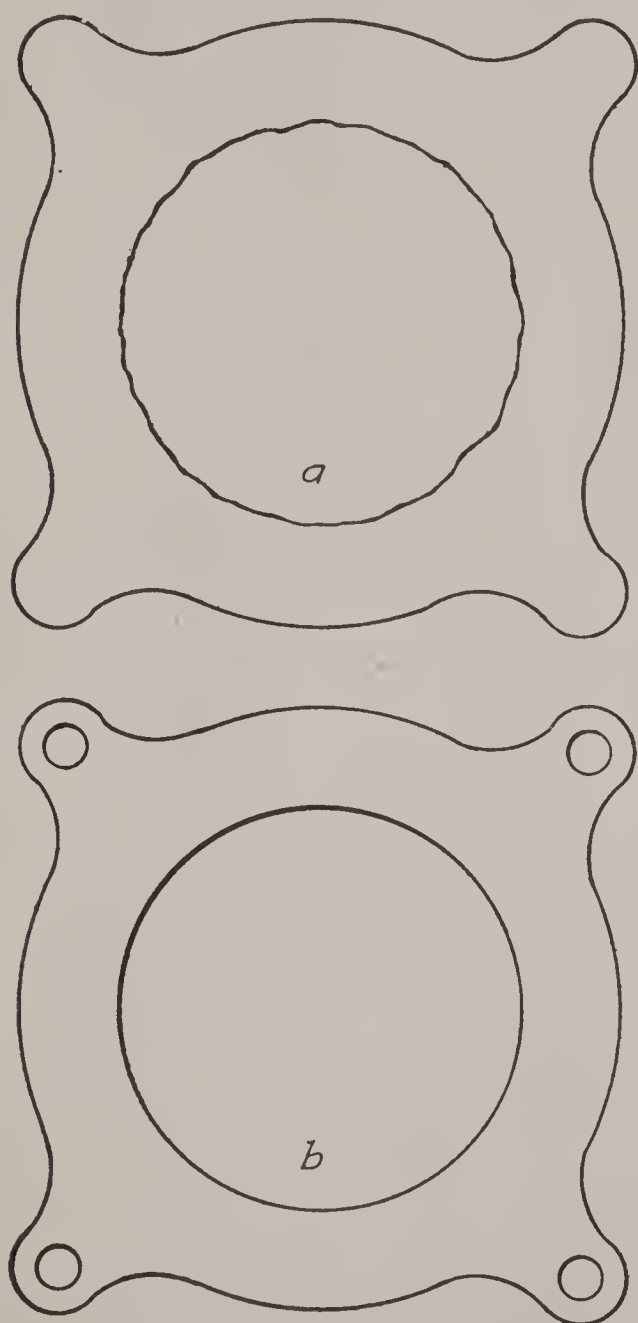


Fig. 57. Carburetor Casting Rough and Finished by Use of Drill Jig

sequence of operations to complete the piece of work is such that the proper operation comes first. For an example, assume that the large hole in the carburetor body was drilled and bored in the first operation and then the holes in the four lugs were drilled while the carburetor body was positioned by the large hole and by the outside edge of one or more lugs. Then the castings would look as in Fig. 60, due to the variation in castings. While, on the other hand, if the tools are designed so that the first-operation jig is one for drilling the four holes in the lugs, and the body is located by the four lugs, then the second-operation jig, for boring the large hole, has 4 pins to enter the 4 holes in the lugs, and if the large cored hole is not central with the 4 holes before drilling, it will be so after boring the large hole, and the 4 holes

in the lugs will be central with the outside lugs.

The designer must not lose sight of this point, for his success depends largely upon his ability to design tools to do the proper operation first and in using the same holes for locating points, if possible, throughout the successive operations necessary to complete the work.

**Essentials in Design.** Other points to remember in designing drilling jigs are the following:

(1) Simplicity in operation.

(2) Rounded ends of stop or of locating points, to prevent chips gathering.

(3) Absence of corners where chips can gather.

(4) Small feet on the bottom of the jig, instead of a broad bearing surface, because chips on the table of a drill press do no harm if 3 or 4 small feet are employed.

(5) Remember that the quantity of parts to be produced should govern the elaborateness of the jig.

**Devices for Rapid Operation.** Figs. 61 to 70 show designs of jigs that the student should become acquainted with thoroughly, as the locking devices and methods of holding the work are applicable to boring, milling, and grinding fixtures, where speed of operation is the prime factor.

*Hinged-Cover Jigs.* The jig in Fig. 61 is of the box type in which the work is held by clamping down the cover of the jig; this type is not intended for accurate work. Fig. 62 shows a similar clamping method, but a swinging cover.

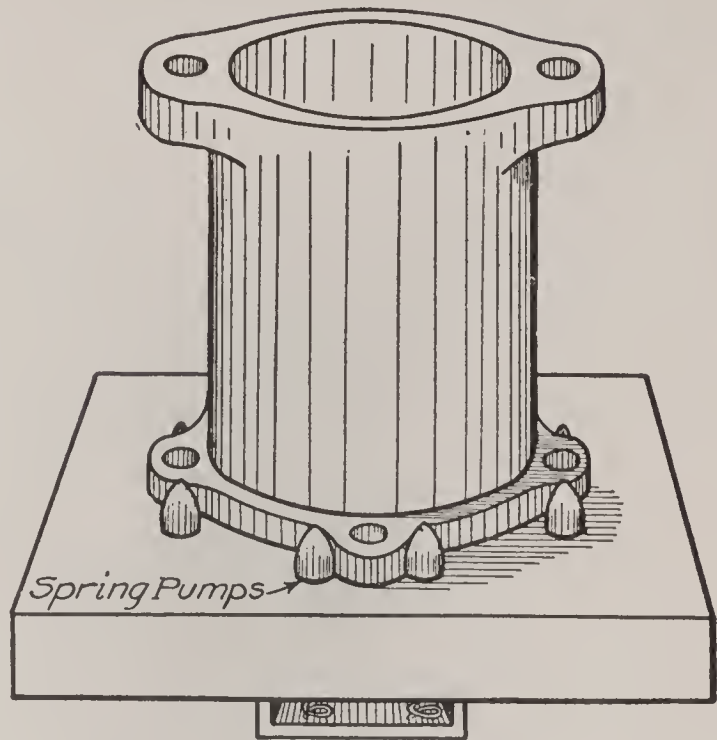


Fig. 58. Carburetor Body Held in Position by Spring Pumps

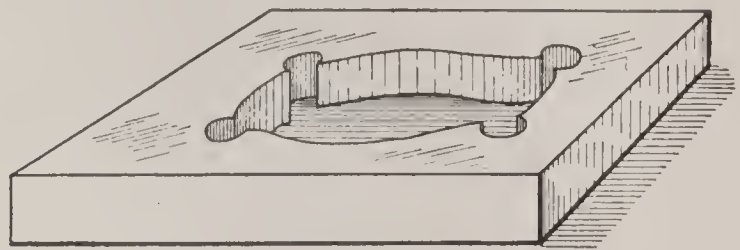


Fig. 59. Nest for Carburetor Blank

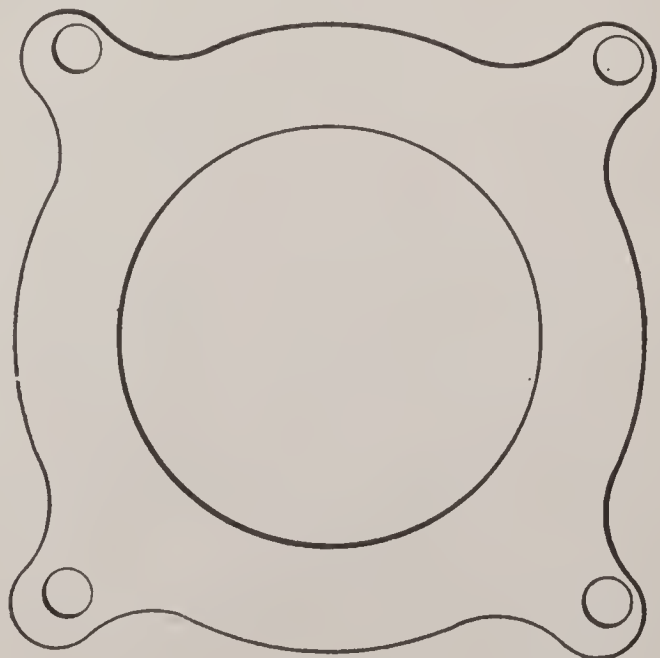


Fig. 60. Possible Inequalities in Drilling Casting Shown in Fig. 57

*Screw-Bushing Jig.* Fig. 63 shows the screw-bushing type. The bushing not only holds the work, but it also acts as a guide for the drill. This type of jig does not produce accurate work, as the free fit of threads on the screw bushing permits it to tilt slightly, changing the center location of the hole in the work.

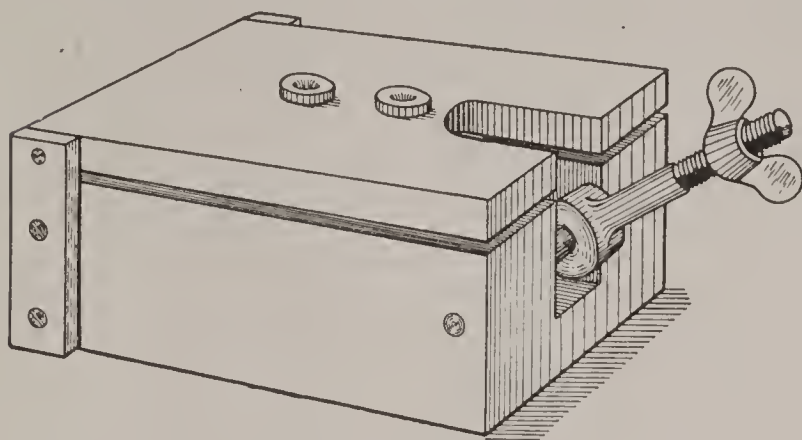


Fig. 61. Hinged-Cover Box-Drill Jig

*Multi-Spindle Jig.* Fig. 64 shows a simple type of jig designed for a multi-spindle drill

press. Clamping devices are not as essential on jigs when a multi-spindle press is used, due to the fact that all drills are cutting at the same time, which prevents the work from shifting.

*Drilling-and-Reaming Jig.* Fig. 65 can be elaborated upon, but the essential point is in being able to drill and ream in the same jig without removing the drill bushing. In operation the work is drilled by the bushings, then the jig is reversed and a reamer or a counterbore further machines the work. A bushing is used for the counterbore, but for a reamer a clearance hole or a soft bushing

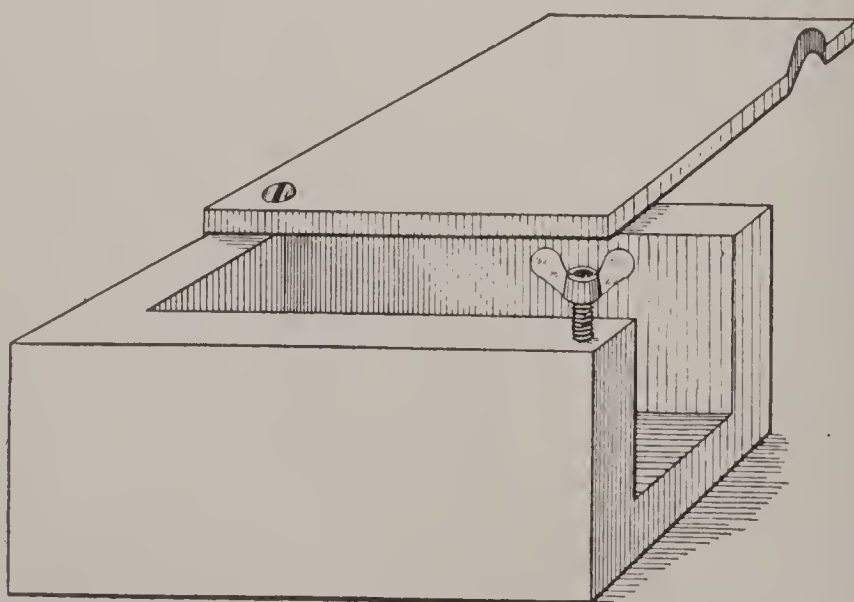


Fig. 62. Box-Drill Jig with Swinging Cover

should be used, as a reamer is rendered useless after it has been reduced 0.001 inch in diameter and wears away quickly while revolving in a hardened bushing.

*Indexing Type.* Fig. 66 shows an indexing type of jig. The object in using the indexing plate is, that when a number of holes are to be drilled in a circle it is a more accurate method than if the jig were made as in Fig. 67. Assuming that the work to be drilled is the plate in Fig. 68, only 1 inch in diameter, then, by making the index plate in Fig. 66, say, 6 inches diameter, and by very accurately locating the index notches in its edge, we could allow slight discrepancies in the notches, for when the variations are reduced to 1:6 they are negligible. A better understanding of this point can be had by noting the difference in travel of the rim of a wagon wheel and the hub.

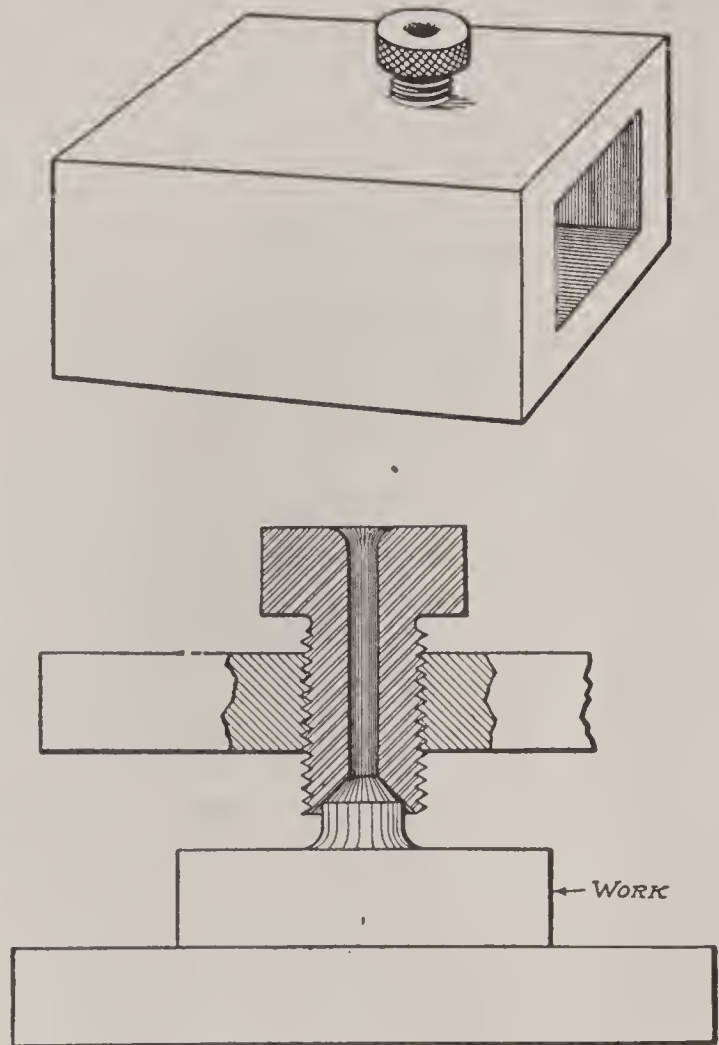


Fig. 63. Drill Jig with Screw Bushing

*Slip Bushing.* The student must bear in mind that the designing of jigs must not be confined to the crude designs shown herewith, but he must become familiar with the principles involved, such as locking devices, methods of locating, etc., and when designing a jig it is often best to embody several principles in a single jig in order to obtain the greatest efficiency. This idea is

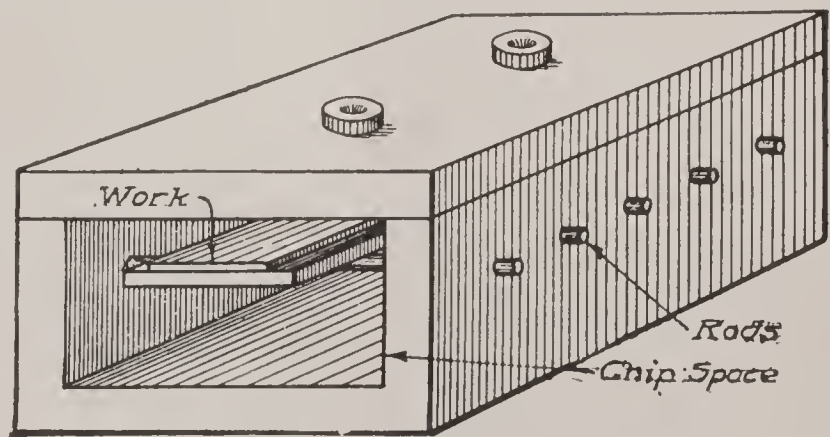


Fig. 64. Box Jig Designed for Multi-Spindle Drill Press

illustrated by slip bushings which are often used advantageously where a reaming, counterboring, or tapping operation is desirable without removing the work from the jig. Fig. 69 shows a plate

which embodies the slip-bushing design, the lower view showing the bushing withdrawn.

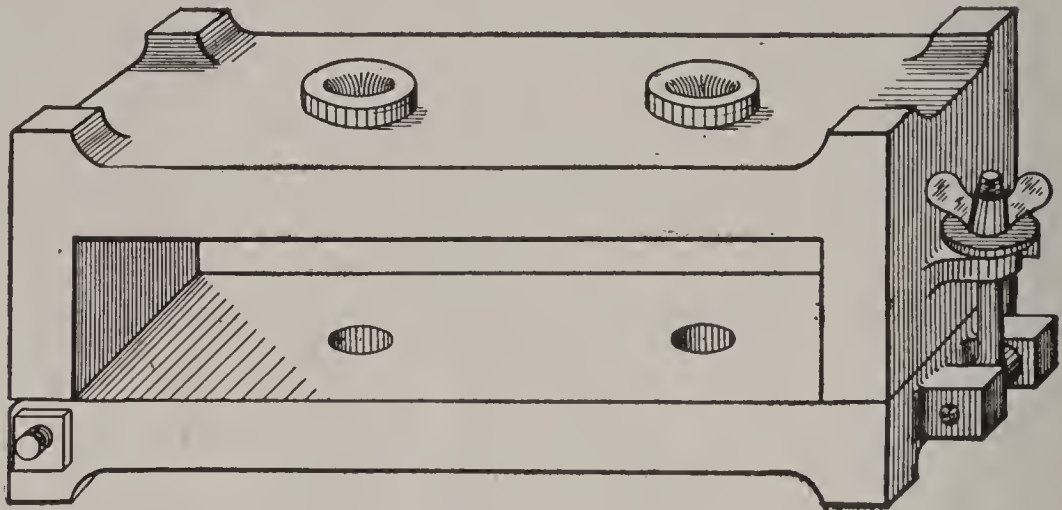


Fig. 65. Drilling and Reaming Jig

*Master-Plate Type.* Fig. 70 shows the most accurate design of jig. It is noted that the jig is attached to the faceplate of a

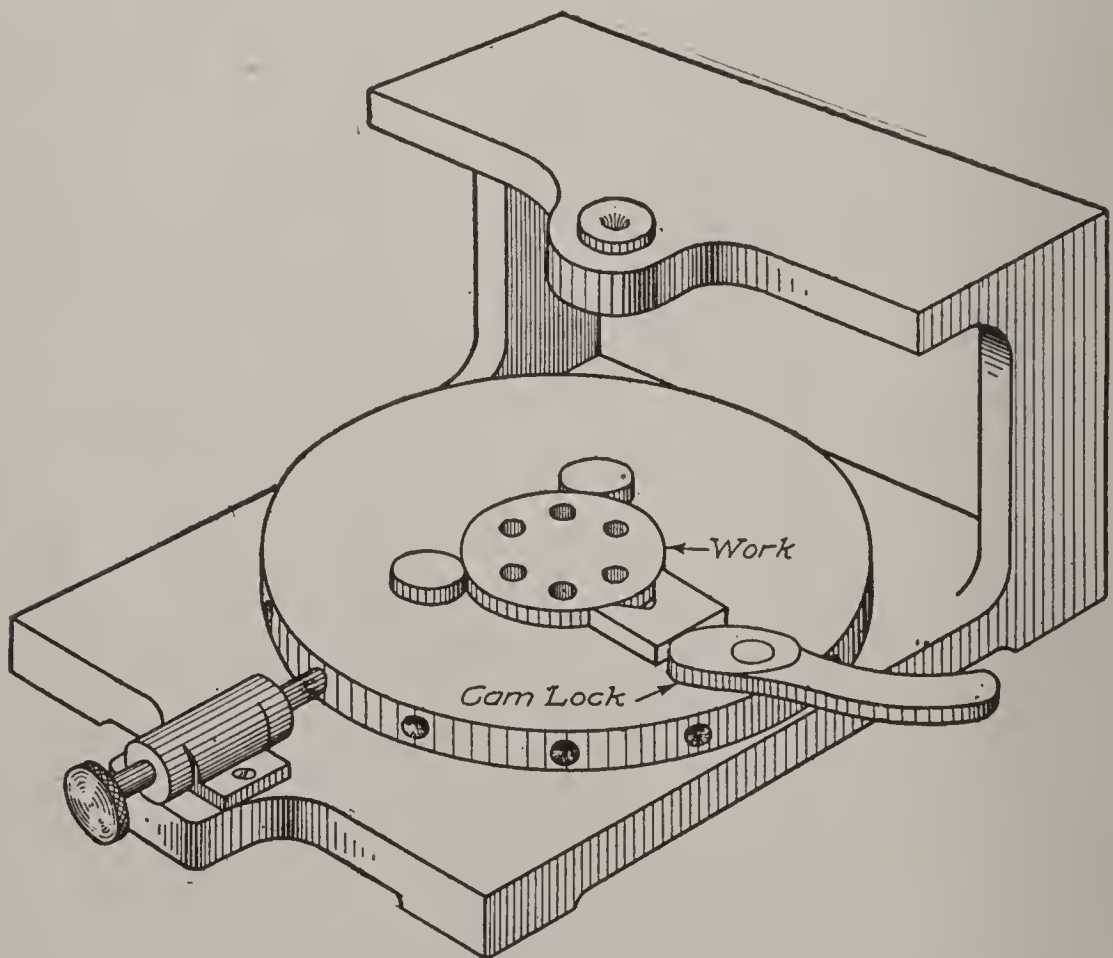


Fig. 66. Indexing Jig

bench lathe and that the jig containing the work is indexed, employing a master plate that has been accurately made and adopted as the shop master. The design shown in Fig. 70 is in its simplest

form, and the designer must exercise his ingenuity in adapting the principle involved to the design of the jig desired. As each hole

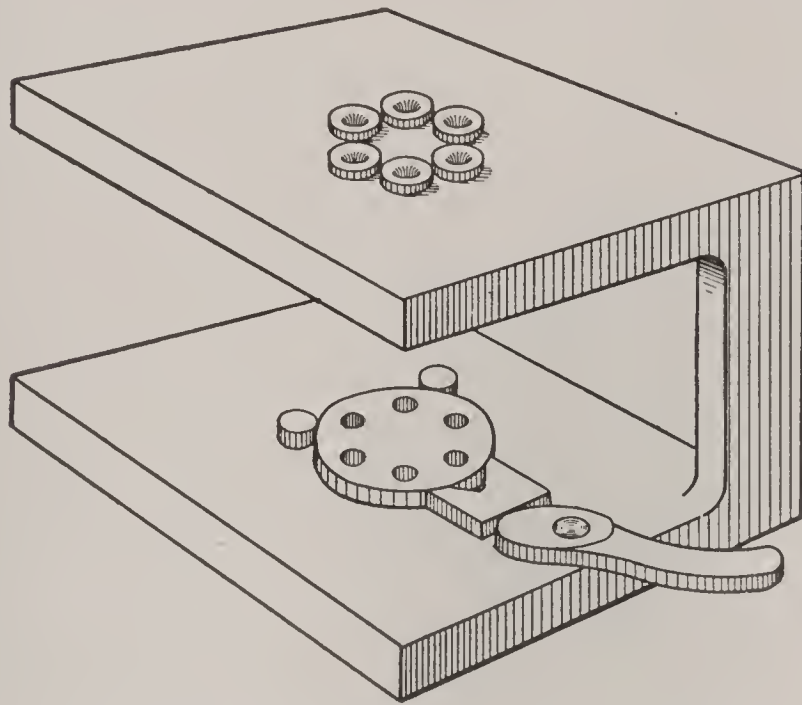


Fig. 67. Simple Method of Holding Circular Piece for Simultaneous Drilling

is spotted and drilled, the hole is made perfectly round and directly opposite the hole in the master plate by boring.

**Boring and Milling Jigs.** Boring, milling, and other jigs are designed

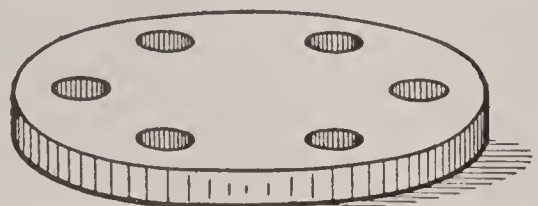


Fig. 68. Drilled Plate

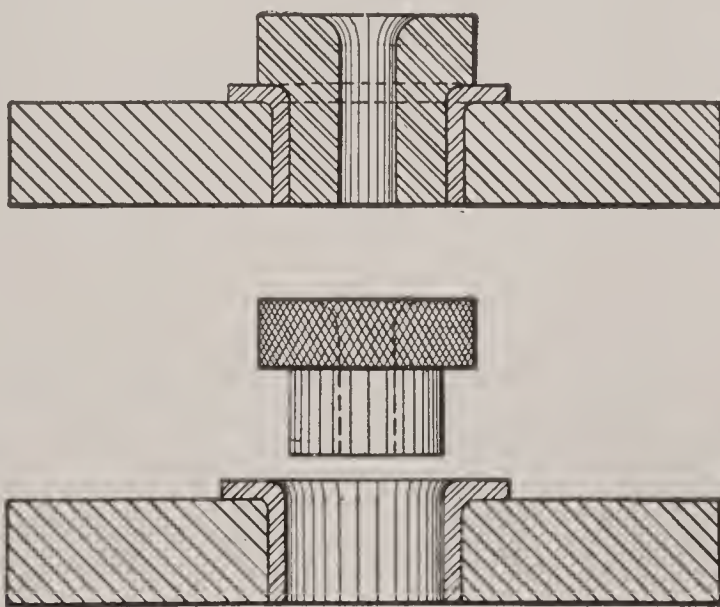


Fig. 69. Slip Bushing

practically the same as drilling jigs, except that they are usually attached to a machine and the holding device, usually a screw clamp, is made more rigid while the machining is being done.

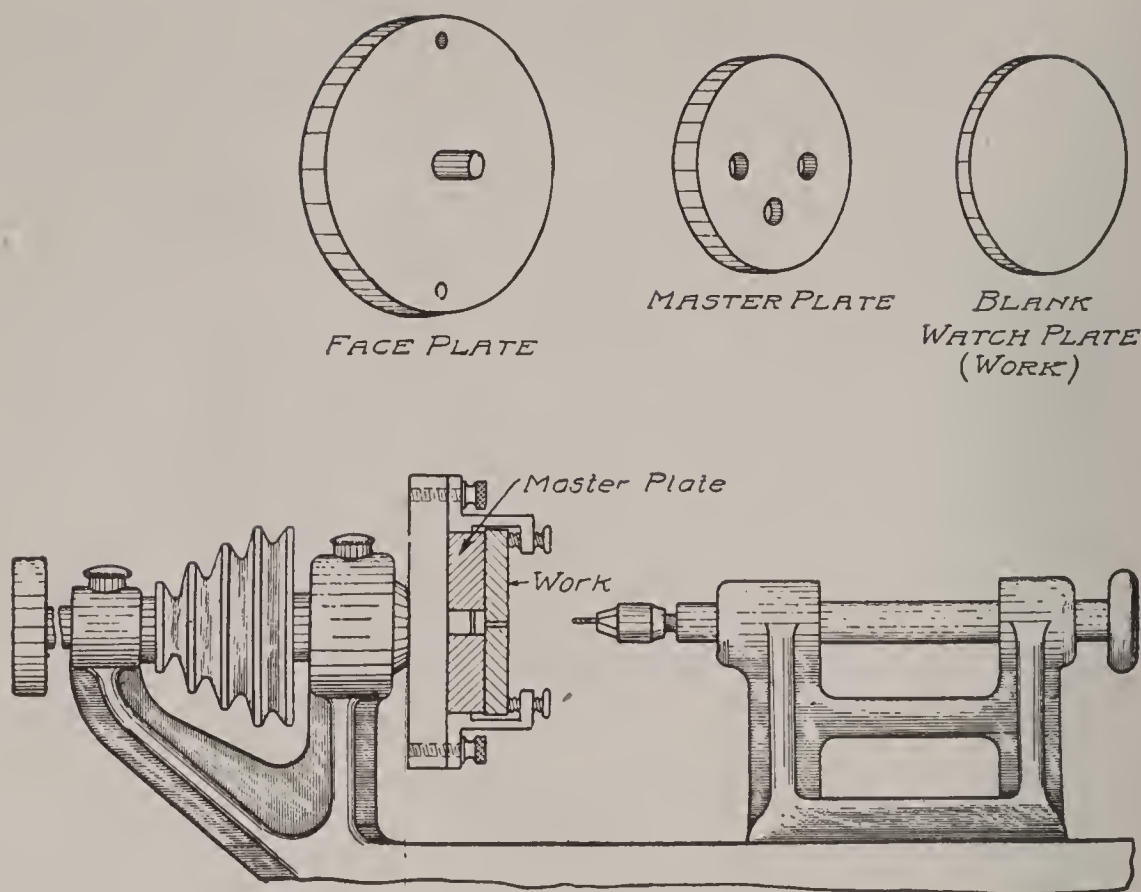


Fig. 70. Master-Plate Jig for Very Accurate Drilling

GAGES

**Classification and Usage.** Gages are classed as ring, plug, snap, depth, male and female profile, receiving, and thread gages.

*Limit Gage.* The close limits to which many products are made to insure absolute interchangeability make it necessary to employ gages for almost every operation, and in many instances *limit gages* are required. Assume that the piece in Fig. 71 is to be

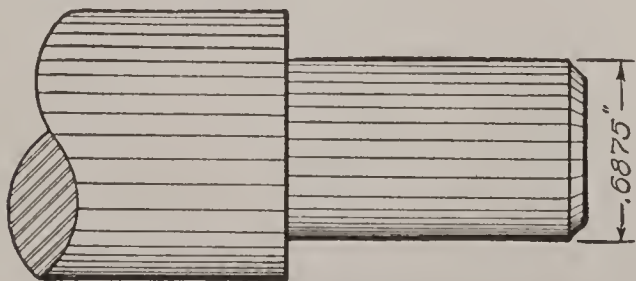


Fig. 71. Example of Piece to be Made of Accurate Diameter

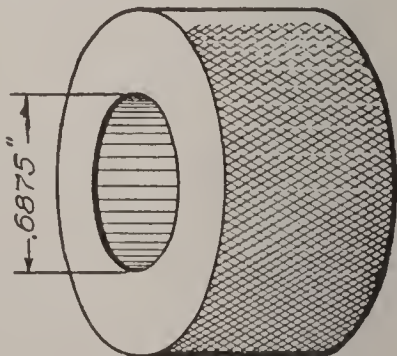


Fig. 72. Ring Gage of Given Diameter

made, which calls for dimensions in tenths of thousandths. It is an unwritten rule almost universally used by designers to specify by the dimensions the accuracy required. For instance, a dimension given in fractions is understood by most tool-makers to mean that scale measurement is accurate enough. When the dimension

is in thousandths of an inch the accuracy must not vary more than one-thousandth, and when a dimension is specified in tenths of thousandths the variation must not exceed a ten-thousandth of an inch.

If a ring gage, Fig. 72, or a snap gage, Fig. 73, made exactly 0.6875 inch in diameter, were given the average operator employed in machining the piece in Fig. 71, the accuracy or variation in the 0.6875-inch diameter would be a matter of personal equation. That is, the gage would not be fool-proof, for as long as the work enters the gage the operator would continue to make the pieces, whereas the diameter might be several ten-thousandths under size.

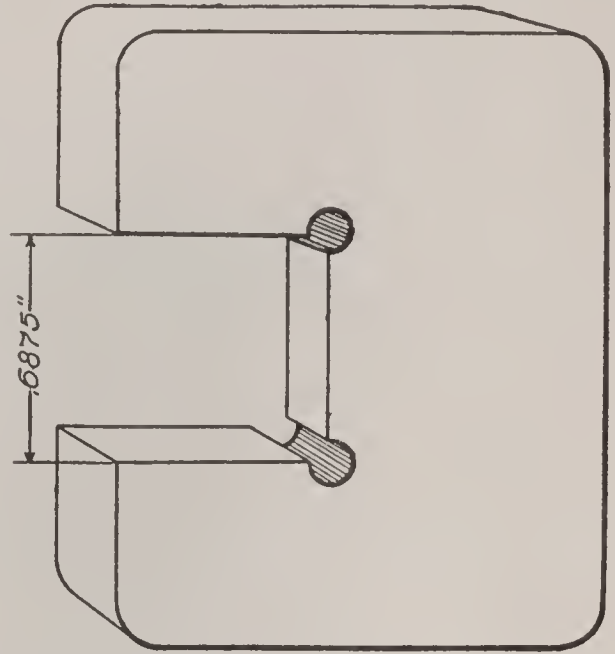


Fig. 73. Snap Gage of Given Diameter

To eliminate this personal equation the gage is designed as in Fig. 74; one gage is made 0.6875 inch, while the other gage is made 0.6874 inch, and in operation, if the work enters the 0.6875-inch gage

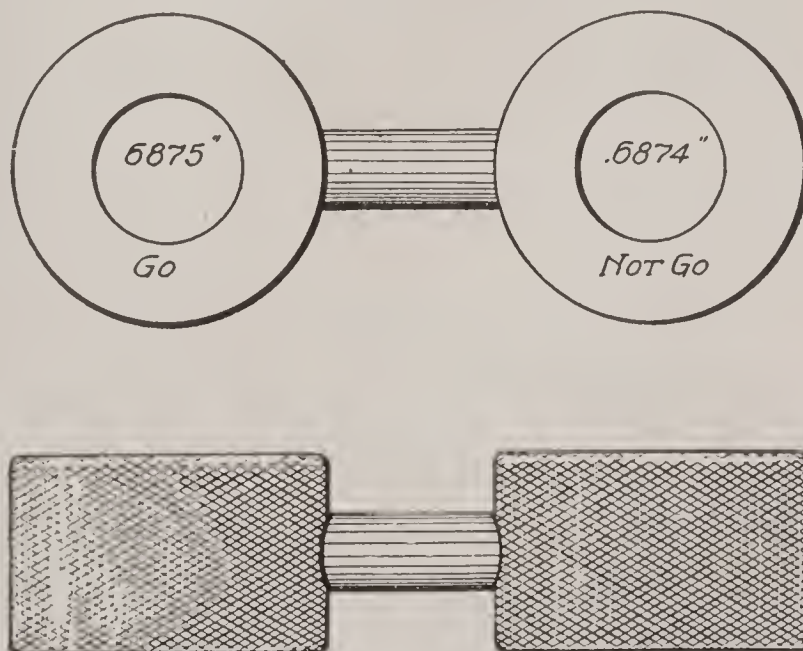


Fig. 74. Limit Gage for Gaging Fig. 71

and not the 0.6874-inch, then the work must be of a diameter somewhere between the two. This type of gage is called a limit gage.

*Snap Gage.* Various designs of limit snap gages are shown in Figs. 75, 76, and 77. The gage in Fig. 77, while more expensive

than the other types of snap gages, is the most suitable design when subjected to constant use. Gages wear quickly, losing their

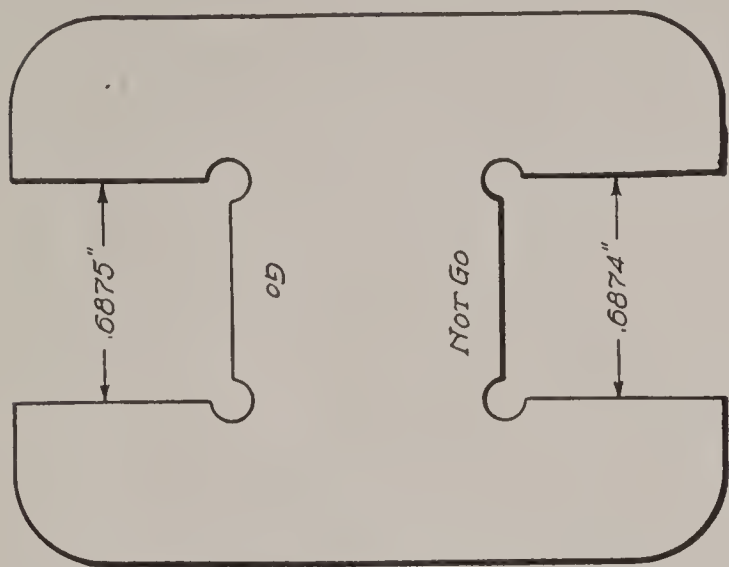


Fig. 75. Limit Snap Gage with Limits Opposed

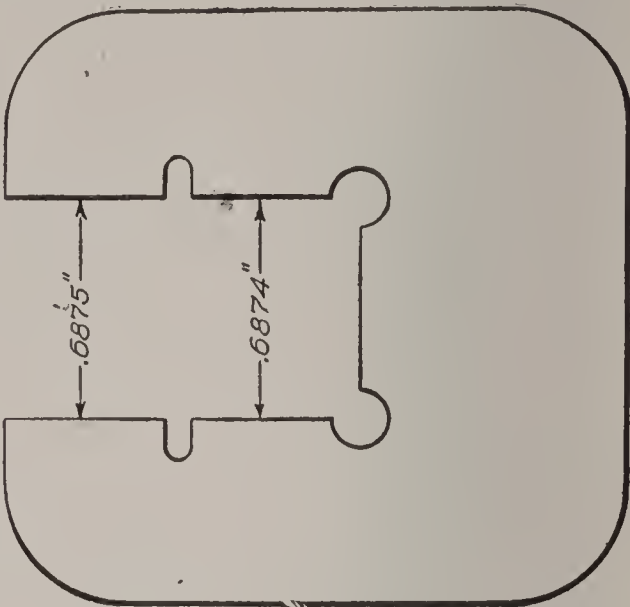


Fig. 76. Limit Snap Gage with Limits in Series

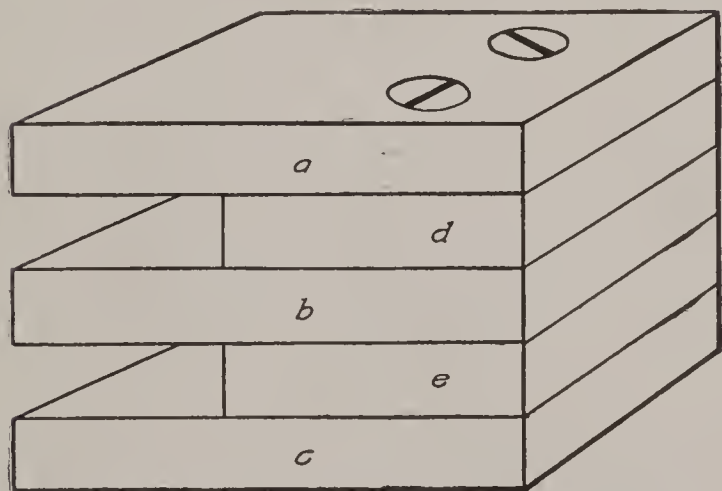


Fig. 77. Snap Gage Designed to Correct Wear

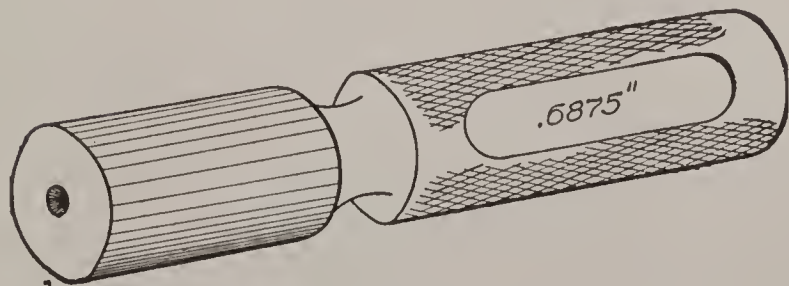


Fig. 78. Circular Plug Gage

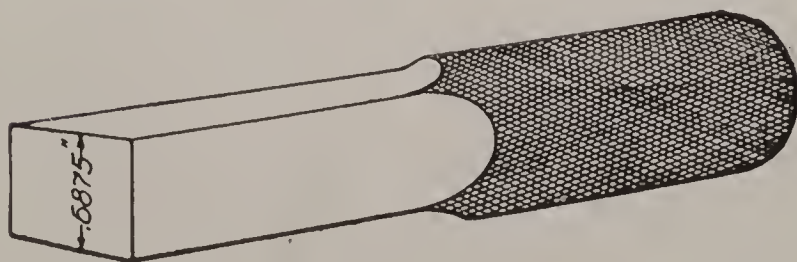


Fig. 79. Rectangular Plug Gage

trueness, and all that is necessary in connection with this latter style is to lap the plates *a*, *b*, and *c*, perfectly flat and to reassemble the gage. The plates *d* and *e* are made of proper thickness, and they accurately space the plates *a*, *b*, and *c*.

*Plug Gage.* Figs. 78 and 79 show the designs of plug gages most generally used. Figs. 80, 81, and 82 show the limit type of plug gage.

*Receiving Gage.* Figs. 83 and 84 show two designs of receiving gages. These gages should be designed for use only when the nature of the work demands extreme accuracy.

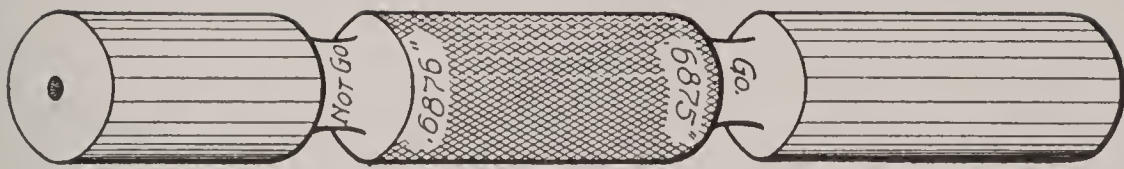


Fig. 80. Plug Gage with Limits Opposed

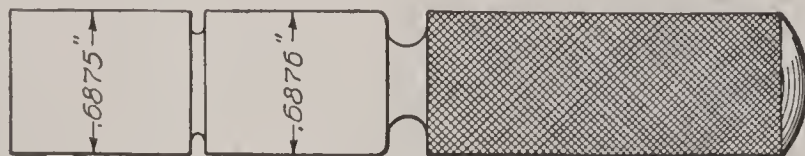


Fig. 81. Plug Gage with Limits in Series

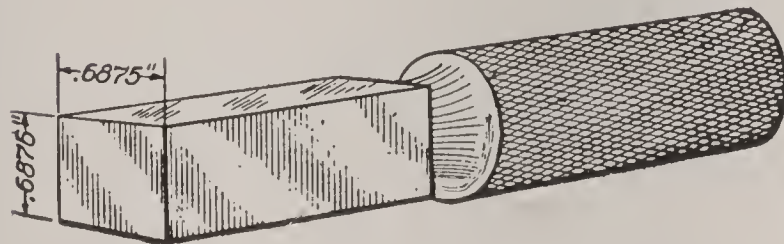


Fig. 82. Square Form of Limit Plug Gage

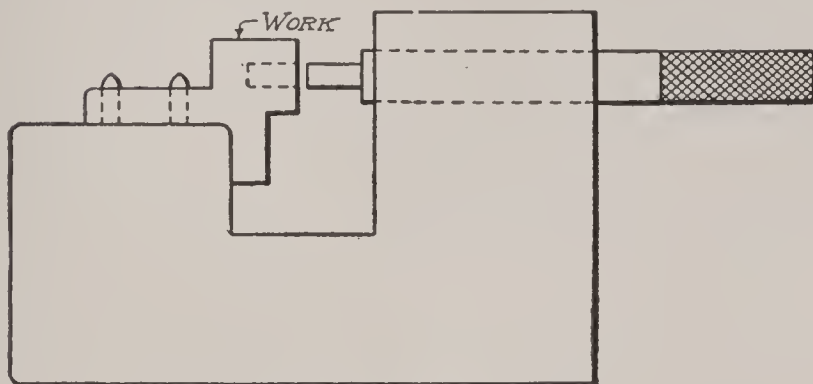


Fig. 83. Receiving Gage

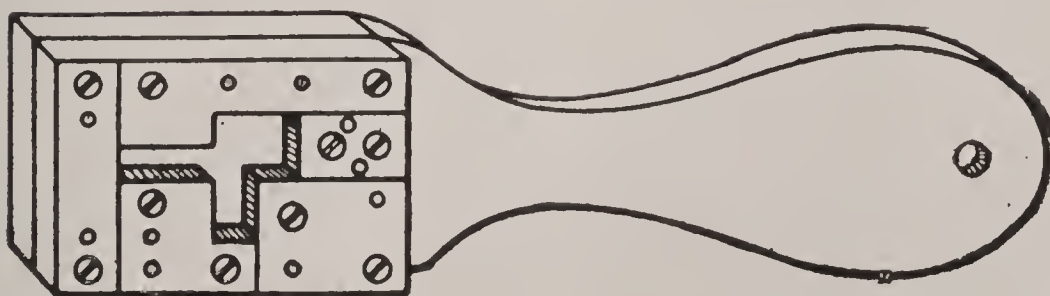


Fig. 84. Hand Form of Receiving Gage

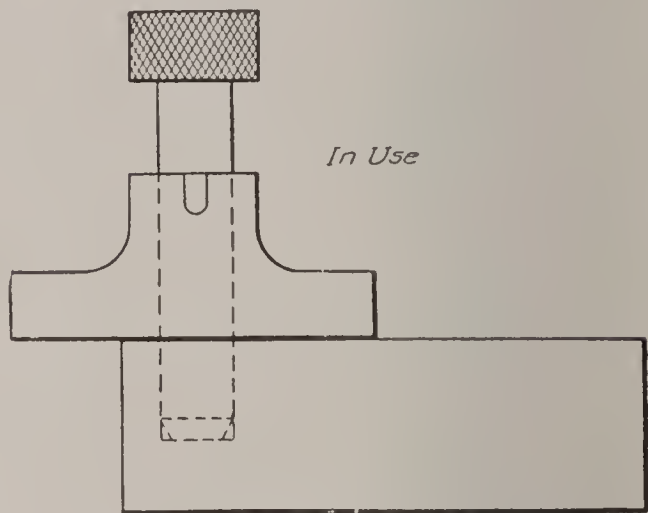
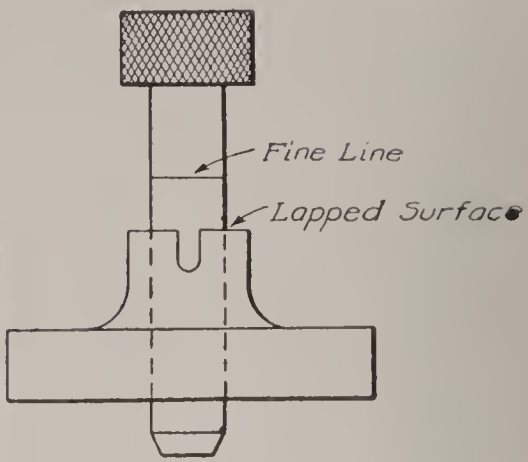
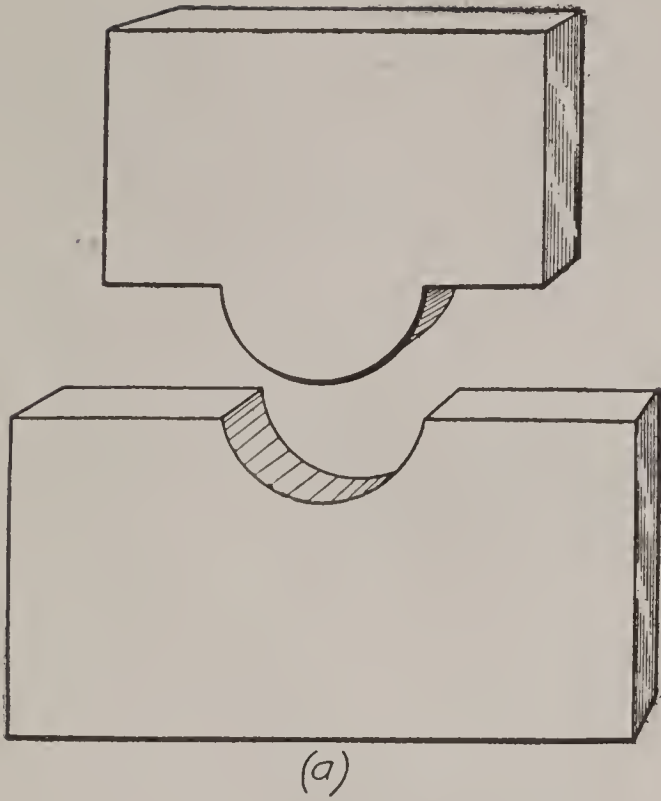


Fig. 85. Simple Forms of Profile Gage

Fig. 86. Simple Depth Gage

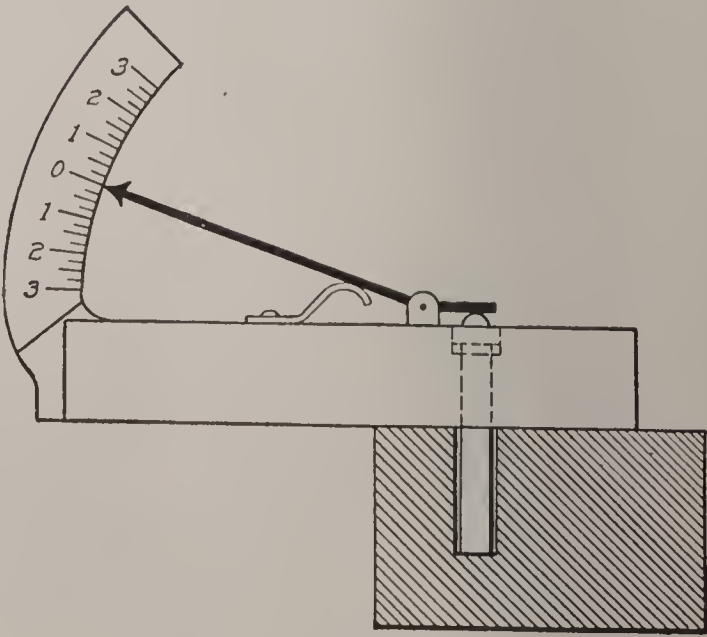
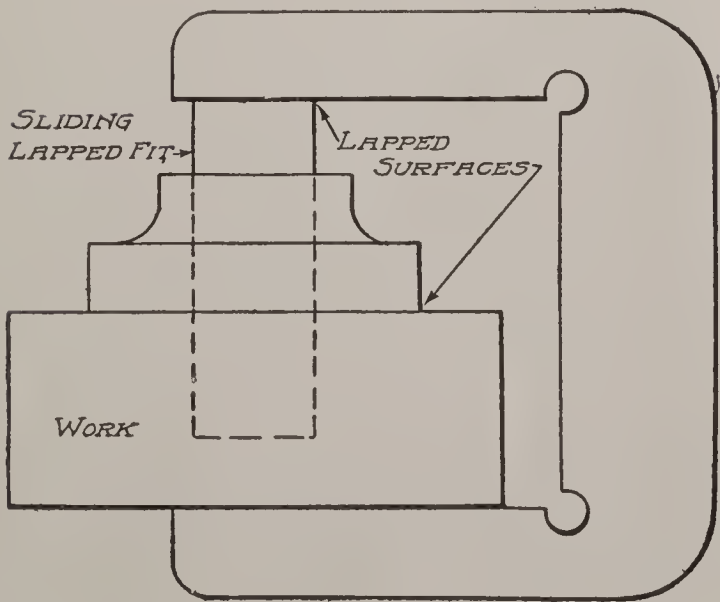


Fig. 87. Depth Gage Depending for Its Accuracy on Operator

Fig. 88. Accurate Depth Gage of Lever Form

*Profile Gage.* When the work is of a nature that it requires a profile gage to maintain the contour or outside shape, the designer should start with a master profile gage to which the profile gages may be fitted for use when making the formed milling cutters, fly cutters, or forming tool, and the working profile gages *a*, Fig. 85. In the illustration the male and female profile gage is in its simplest form.

*Depth Gage.* Figs. 86, 87, 88, and 89 show depth gages. The gages in Figs. 88 and 89 are designed for very accurate work, while the accuracy of those in Figs. 86 and 87 is governed by the operator.

*Bench Micrometer.* The gage shown in Fig. 89 is called a bench micrometer, and there are several good makes on the market. This gage can be used in place of snap, ring, and depth gages.

When used as a thickness gage, the work is laid on the table which is adjustable up or down, and in operation the gaging point actuated by the hand lever is brought to bear on the work, and the thickness of the work is indicated by the pointer on the dial in thousandths of an inch.

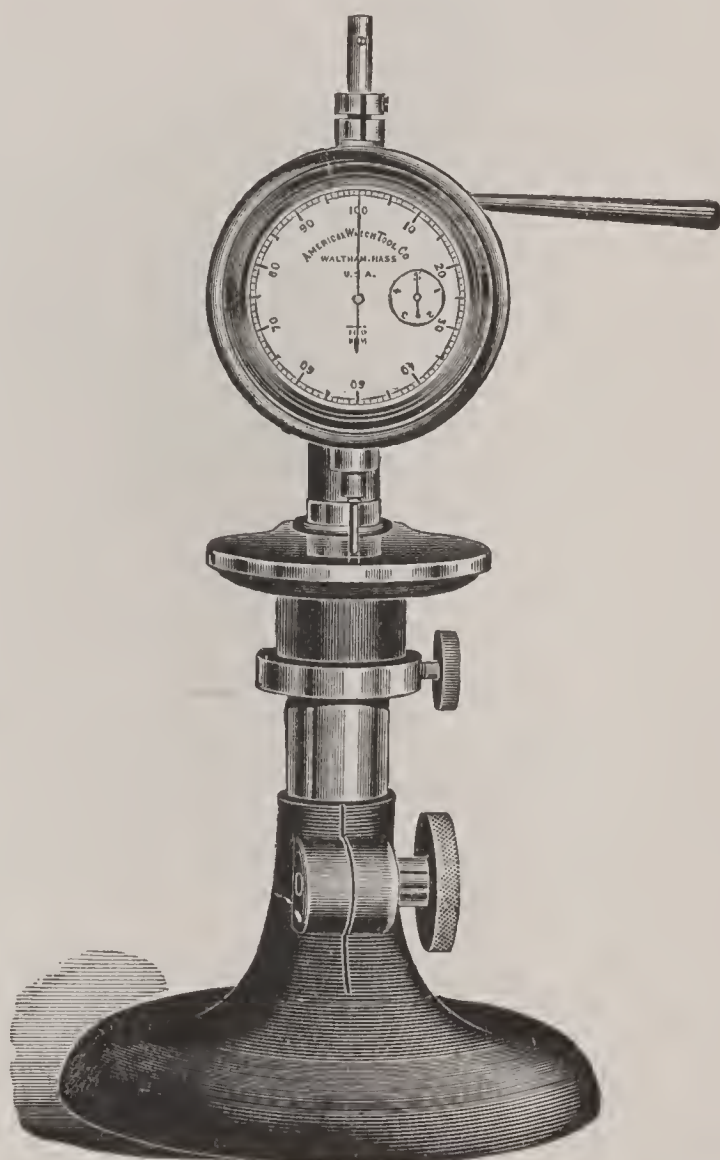


Fig. 89. Dial Depth Gage  
Courtesy of American Watch Tool Company,  
Waltham, Massachusetts

## SUCCESSFUL DESIGNING

**Problem of Sequence of Operations.** The economical manufacture of a product does not depend solely upon the proper design of tools; the sequence of operations through which the product passes also plays a very important part. Therefore the designer may tool up for a certain product, and the tools may be of the best

design imaginable—embodying quick loading and unloading features and clever locking devices, all of which tend to make the rapid handling and completion of the parts all that may be desired—

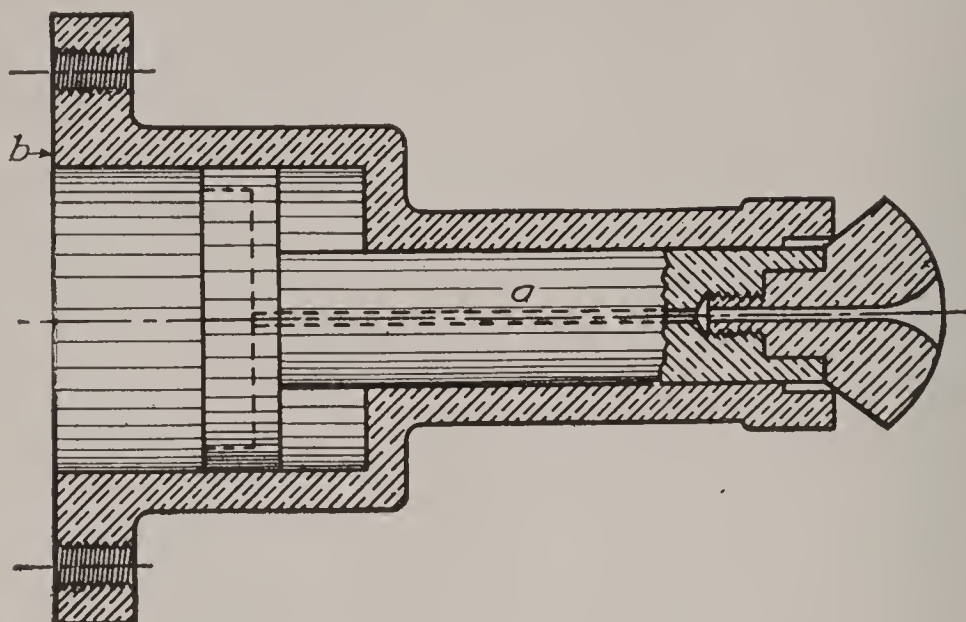


Fig. 90. Carbureter Body Shown in Section

but the actual economical feature can be lost through not doing the proper operation first, and it too often happens that a third tool is made necessary to correct discrepancies that are caused by the improper sequence of operations.

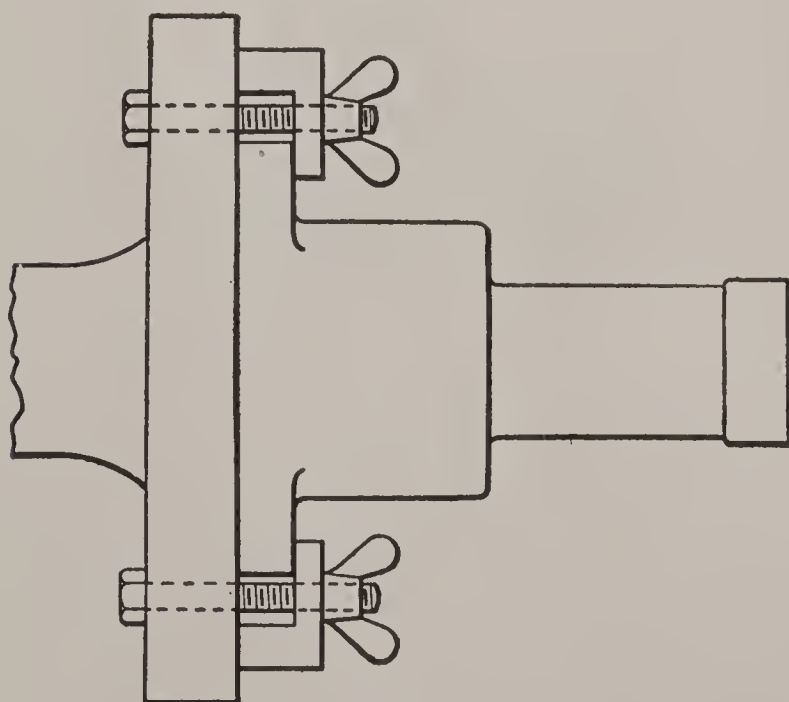


Fig. 91. Carbureter Body Clamped to Faceplate

The difference in diameters between the inside bore of the body and the outside diameter of the valve *a* is limited to not more than 0.002 inch.

The following line of reasoning must be followed to be a successful designer:

The carbureter body, Fig. 90—with its thin delicate walls, the two bores which must be absolutely in line, and an outside of rough casting scale—is an excellent product to demonstrate the necessity of carefully laying out the proper operations before designing the tools. The difference in diam-

**Manner of Holding Work.** *Distortion by Chuck Jaws.* The first thought naturally would be to grip the body in a chuck having special jaws to hold it, but the fact that the outside of the body

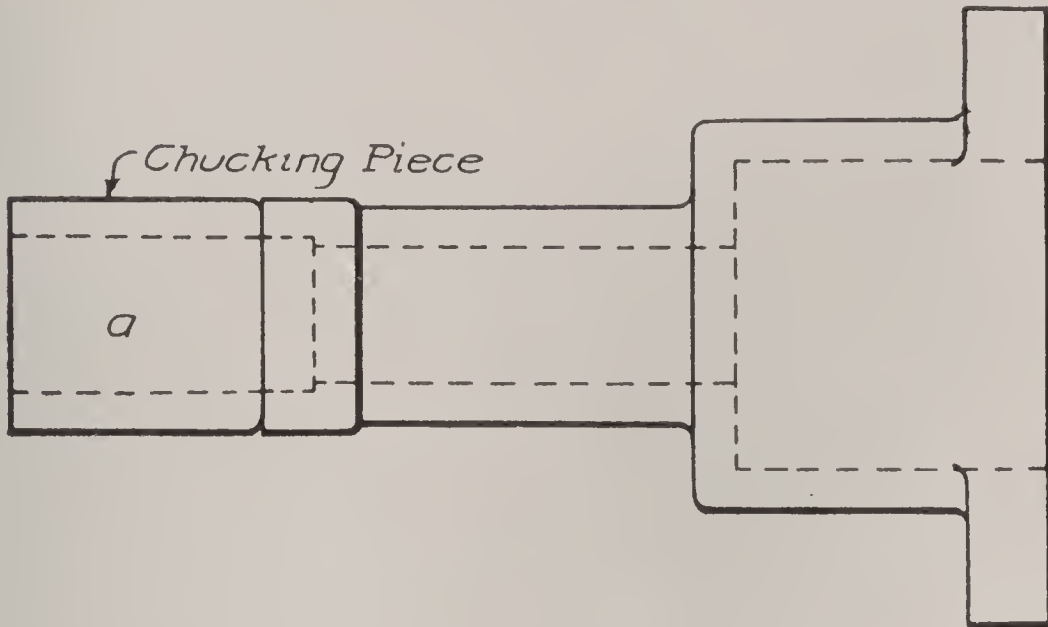


Fig. 92. Holding Small End of Carbureter Body by Means of Chucking Piece

is a rough casting and the walls are thin precludes the use of chuck jaws, for the reason that one small high spot on the casting would cause the pressure of the jaws to center on this high spot, resulting

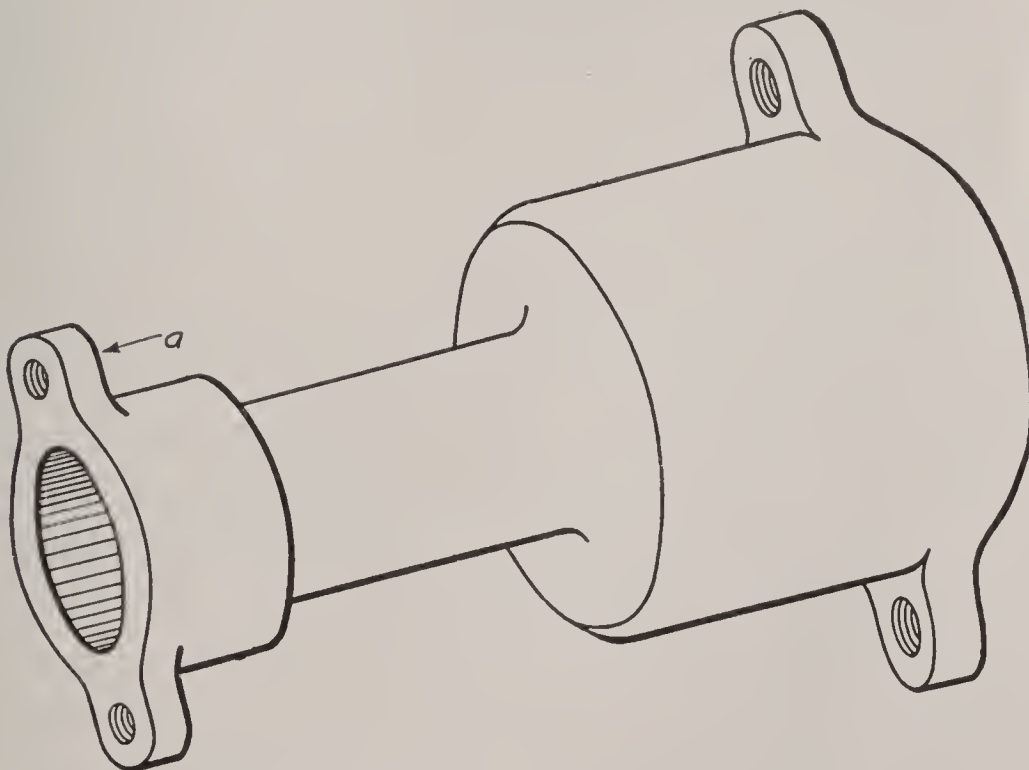


Fig. 93. Carbureter Body with Special Lugs for Holding

in distortion of the body; then, if the body were finished while under distortion, the finished hole would be out of round when the pressure is released. This fact makes it necessary for the designer to depart

from the usual design of tools and to devise special tools, depending almost entirely upon his inventive ability, and upon a fund of experience and knowledge of every conceivable mechanical device. From his knowledge he must mentally select a certain principle

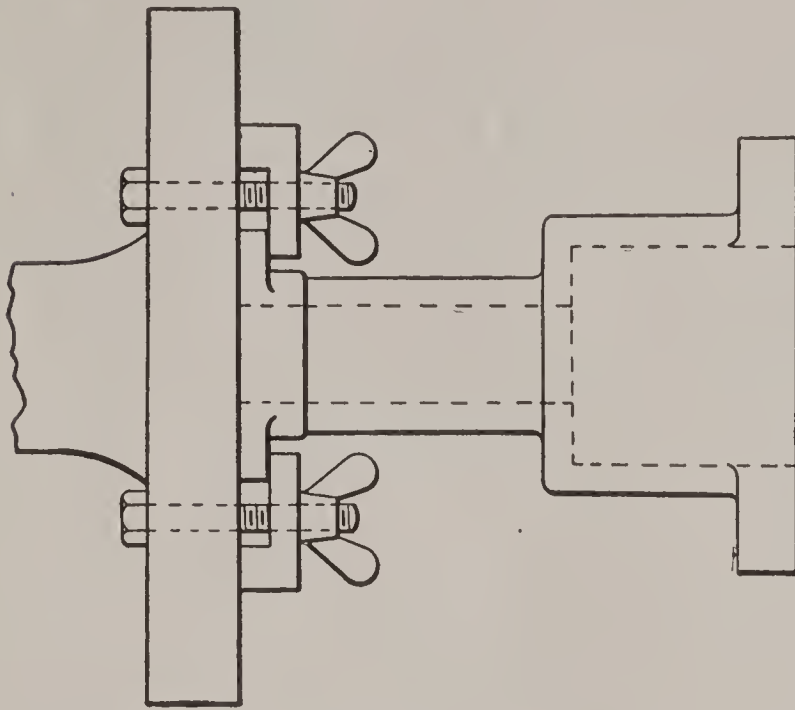


Fig. 94. Carbureter Body Held by Faceplate with Special Lugs

involved possibly in some one jig, and another principle or movement embodied in some other fixture, and so on, until by putting these together he can complete a satisfactory tool to meet the requirements of the operation at hand. Therefore a method other than chuck jaws must be devised for holding the body for the first operation.

The thought occurs that the wide base *b*, Fig. 90, is an excellent surface to clamp against a lathe faceplate containing special holding

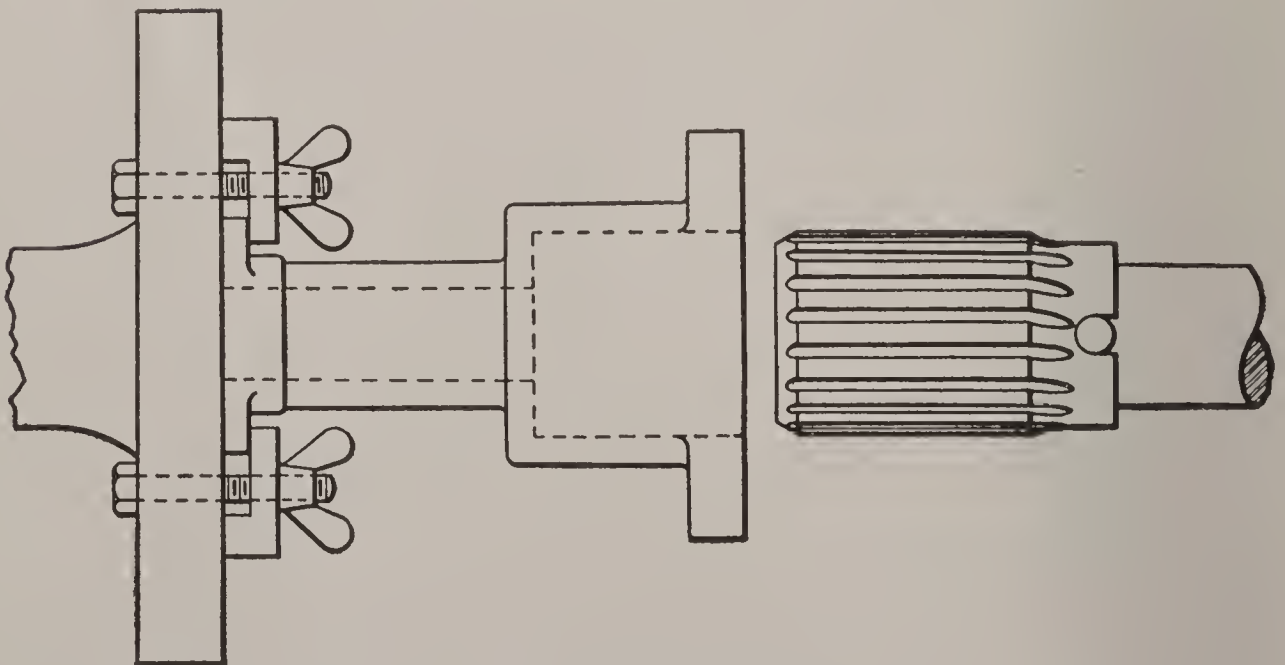


Fig. 95. Lathe Set Up for Roughing Cutter

fixtures as in Fig. 91. However, the designer immediately discards this method, for it is noted that the larger bore cannot be machined in this position, and, as the two bores must be in absolute alignment,

it would mean that the work would have to be machined first on one end and then on the other, which is decidedly wrong, for eccentricity will creep in. Following the rule of machining as many surfaces as possible at one setting, a device must be employed that holds the work by the small end, so that both diameters can be finished at the same setting and while the body is not under distortion. By so doing, absolute alignment is possible.

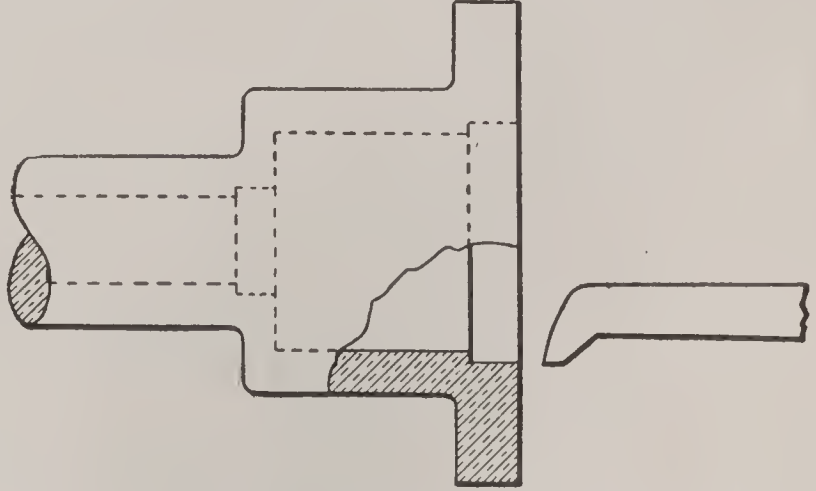


Fig. 96. Inside Hole of Carburetor Body Recessed before Using Roughing Cutter

#### *Use of Chucking*

*Piece.* The problem now at hand is to satisfactorily hold the body by the small end.

A chucking piece *a*, Fig. 92, could be cast on the body simply to provide a holding member, then after the body is machined the chucking piece could be cut off. This chucking piece could distort the body in two ways: (1) by the pressure of the chuck jaws on the chucking piece; (2) since in all castings there are internal strains and, to a great extent, the scale prevents these internal strains exerting themselves, the process of roughing out the bores to remove the strains, then final-finishing the bores, and lastly, severing the ring or chucking piece would further release the strains, and the finished bore on the small end of the body would not be round.

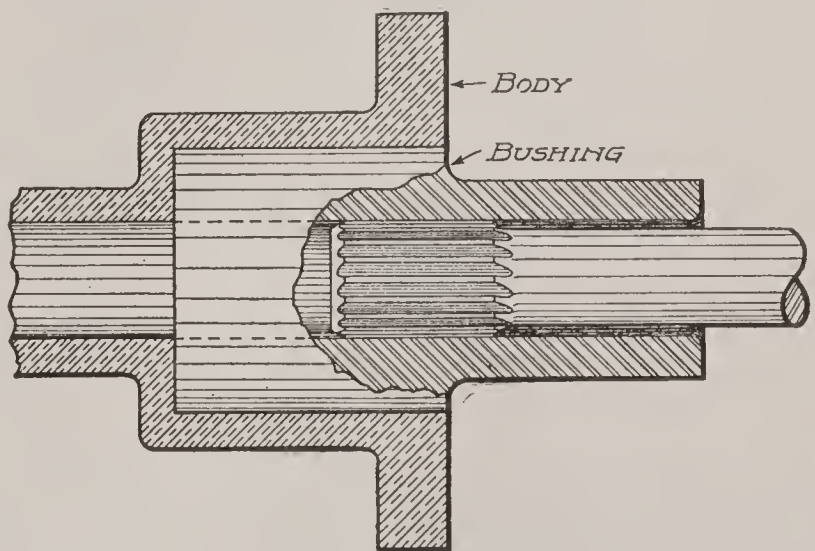


Fig. 97. Use of Guide Bushing in Boring Central Hole

#### *Special Lugs.*

Knowledge of these facts

leads the designer to add a special lug *a*, Fig. 93, on each side of the body, and the body is finished complete at one setting, as in Fig. 94, the lugs then being cut off, or, if possible, left on the body. The design of the body or product at hand can often be cleverly



the cutter follows the hole, and, after a finish reamer machines the large bore, the diameter may be correct but the bore is still running eccentric. Therefore, to insure the roughing cutter starting centrally, the outer end of each bore is recessed to cutter size for a short distance, as in Fig. 96, using a single-pointed boring tool. The roughing cutters mounted in the turret head of a monitor lathe can then be used to rough out the bores, due allowance being made to leave enough stock for the finish tool to clean up the hole. For absolute alignment of bores a single-pointed tool should be used to finish-size both bores, for a reamer cannot be depended upon to keep the hole concentric, although it produces the desired diameter.

*Use of Guide Bushing.* Another method of machining the bores would be to rough out both bores to remove the scale, then finish the large bore and insert in it a concentric hardened-steel bushing, Fig. 97, the central hole in which is used to guide the cutter for finishing the small bore. The student, however, can readily see wherein there are chances for inaccuracies to creep in when the bushing is employed. "How many chances for errors?" would make an excellent examination question. The answer is three, as follows: (1) difference between diameter of bushing and bore in body; (2) difference in diameters of hole in bushing and of reamer; and (3) eccentricity of hole in bushing.

**Conditions for Accuracy.** The points that must be considered by the designer to produce the carbureter body, or similar work where holes must be in absolute alignment or concentric with outside, and where holes must be perfectly round, are as follows:

- (1) Use a holding device that does not distort.
- (2) Lay out the sequence of operations so that the work can be completed in the least number of operations.
- (3) Do all machining that is feasible at one setting, to insure concentricity.
- (4) Do not trust a reamer to final-size holes that must be in line with each other.
- (5) Do not machine one end then reverse the work and machine the other end, if possible to avoid, for any error caused in either end is doubled when the work is reversed.

(6) When finish-sizing holes or circular outsides that must be in absolute alignment, use a single-pointed tool, not guided.

(7) It makes no difference whether the work revolves and the single-pointed tool is stationary, or whether the single-pointed tool revolves in work that is stationary.

The valve *a*, Fig. 90, of necessity must be made just as accurately as are the bores in the body, and the same ideas must be followed out as were outlined in connection with the body, i.e., do all turning possible at one setting, using a single-pointed tool to guard against eccentricity, etc.

**Outlining Methods.** To complete the outline of tool design—supplementing the question of why a certain design is adopted—and to enumerate the detailed methods that must be followed by the designer, assume that you have been given a blue print, Fig. 98, which gives the detailed dimensions of the three pieces shown in Fig. 90, and that you are instructed to proceed with the tooling up for a large production job.

*Order of Operations.* The first step is to procure a long strip of paper and rule it, or to have a quantity printed, as in Fig. 99, for a data sheet. The next move is to select piece No. 1 and lay out the sequence of operations by mentally going over each operation necessary to complete the piece satisfactorily. The order of operations as finally decided upon is enumerated on a pad in numerical order, Fig. 100.

*Tools Required.* After all pieces have been thoroughly gone over many times and the final operations written out, the next step is to outline the tools required. On the data sheet are written the operations and all the tools required, even to standard drills, reamers, etc., as in Fig. 99. The tools are then assigned a number for record purposes.

*Correlation of Units.* Before designing each tool, a careful classification should be made so that the tools designed first shall produce a secondary unit. For example, a product is made up of pieces parts, which in turn go to make up a secondary unit, and the secondary units finally make up the primary unit, which is the completed product. A graphical illustration is partially shown in Fig. 101. The object in designing the tools so that a secondary unit may be completed is that, as fast as the tools are made, trial

models should be made from the tools and the trial models, if they are piece parts of a secondary unit, can be assembled one to the other, making an assembly of a secondary unit which is a check on the tools. If a tool were made to produce the float in a carbureter, and the next tool made produced the air valve, these tools could not safely be allowed to run off a quantity of pieces until all tools were completed and a trial model assembled from pieces made from the tools. In the arrangement in Fig. 101 the 1-inch carbureter is of course the primary unit; the throttle-body assembly and the float assembly are both secondary units that go to make up

Dwg. No. C-292  
Piece No. 1

TOOL DATA SHEET

Operation No.	Description	Tools Required	Tool No.		Dwg. Completed	Machine	Dwg. given Tool Room
			Old	New			
1	Form thread & cut off (Rough)	Box Tool .248-24 Dia.	104			Automatic	
		Snap Gage .575"		403	12/2/15	"	12/3/15
		Female thread ga. (Rough)		404	12/2/15	"	
		Profile Gage		405	12/2/15	"	12/3/15
2	Drill & flare hole and finish turn	Screw chuck	95			Bench Lathe	
		Spotting tool		407	12/3/15	" "	12/4/15
		1/16 Drill		Stock		" "	
		Drill chuck		"		" " "	
		Forming tool for flare		408	12/3/15	" "	12/5/15
		Snap ga. .562"		409	12/4/15	" "	12/5/15
		Profile ga. (Finish)		410	12/4/15	" "	12/6/15
		Ga. for flare		411	12/4/15	" "	12/6/15
3	Inspect	Female thread gage		404	12/4/15		12/6/15
		Profile gage		410	12/4/15		12/6/15
		Snap Ga. .562"		409	12/4/15		12/6/15
		Gage for flare		411	12/4/15		12/6/15
							12/6/15

Fig. 99. Order of Performing Operations

the primary unit, while the pieces that make up the secondary units are piece parts. If the designer will systematically lay out the tools and parts as outlined, the danger of missing some tool or piece may be reduced to the minimum.

**Design of Product.** Another point that governs the design of tools, and in a sense comes within the tool designer's domain to a great extent, is the design of the product. In up-to-date engineering departments the product designer consults the chief tool designer before turning over to the tool designer the finished product for tooling up. For instance, a model device may have

been perfected of sheet metal, but certain parts of this device are held together by screws, which means tapping operations and the cost of screws besides the slow operation of putting in the screws.

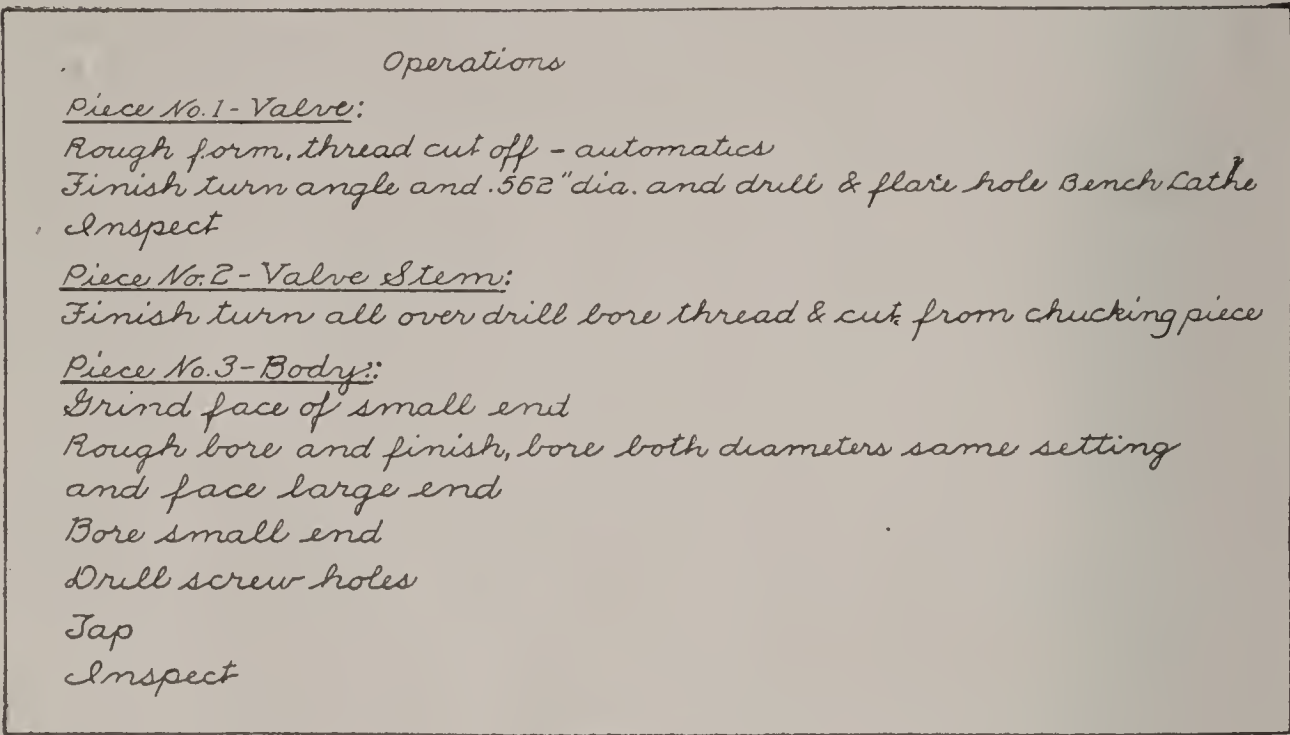


Fig. 100. The Units and Their Classification in Any "Tooling-Up" Process

The tool designer, due to his training, notes that these certain parts could be held together satisfactorily by punching and bending down an ear, which in turn fits in a slot and is then riveted over, or bent over, eliminating the tapping and the cost and handling of screws.

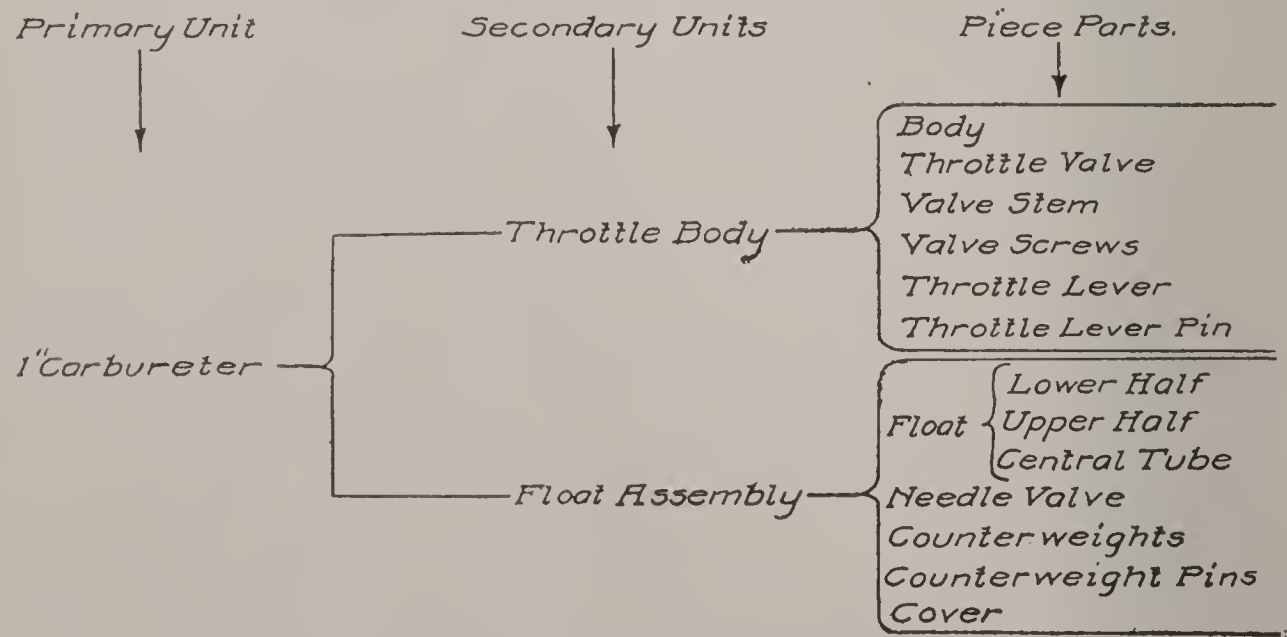
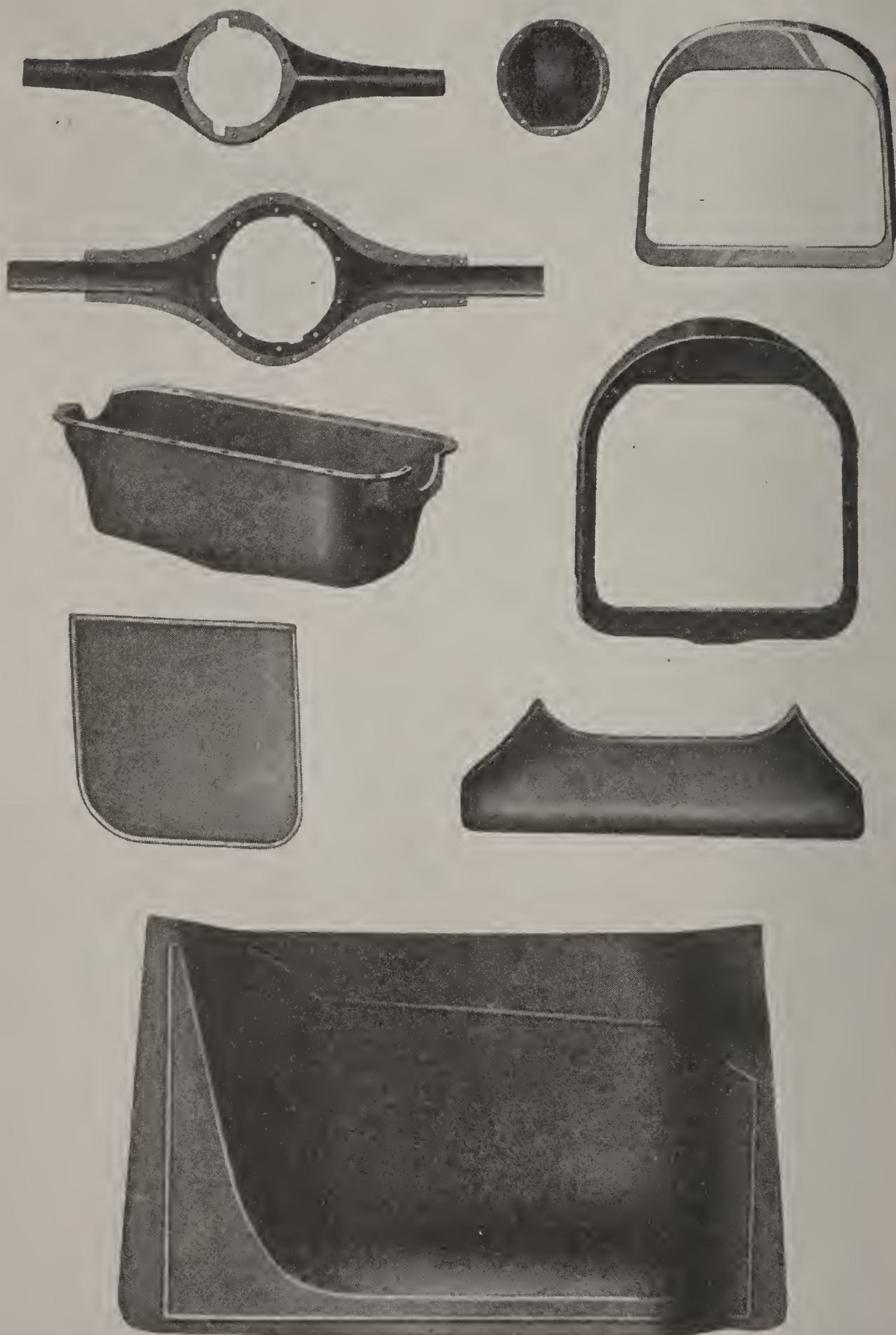


Fig. 101. Diagrammatic Layout of Carburetor Operations into Units

**Collaboration.** The successful designer does not depend entirely upon his own ideas, but obtains the views of all interested. There is a shop phrase that "there are forty-nine ways of doing

every job'', and a designer who places himself upon a pinnacle and refuses to confer with designers and tool-makers under him or with the foreman who is to use the tool always wonders why he does not advance, and this type of designer will be found too frequently looking for a new position. Oftentimes the foreman who is to use the tool may recall some particular job that is identical with the one at hand, and can greatly aid the designer. Therefore, the designer must not allow personal pride or conceit to govern his work, but should make it a practice to get every idea and to listen to every suggestion possible. While a suggestion may not be applicable to the job at hand, it should be mentally retained and sooner or later may be employed.

**Observation.** Observation plays an important part in making a successful designer. For instance, should the designer see in operation some complicated machine or fixture, he should at least make it a point to note mentally one or more movements, even if the entire principle of the machine cannot be grasped at a casual glance. The reading of journals devoted to the mechanical field is one of the greatest aids to success; every article contains some unique kink or valuable point, and a reader may grasp in a few minutes' reading what has required years of travel and experience for the author to gather.



**TYPICAL AUTOMOBILE STAMPINGS**

*Courtesy of Toledo Machine and Tool Company, Toledo, Ohio*

## PART II

# DIES AND SHEET METAL STAMPING

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### DIE-MAKING AND USAGE

**Study of Details.** Having become familiar with the various types of dies for stamping sheet metal, together with a general idea as to the methods employed in making the dies as outlined in a general way in Tool-Making, Part III, it is now essential that the student thoroughly understands the manner in which a die-maker sets about to satisfactorily complete any die. This article deals with die-making proper, entering into each minute detail and description of the various methods and shop kinks practiced by the expert die-maker, together with a description of why a certain piece is made first, and why it is made a certain way; taking up the next piece, and from this to a third, and so on step by step, until the completion of the die.

*Grasp of Job Essential.* The first step practiced by an expert tool-maker when about to make any tool is to thoroughly understand the drawing from which he is to work; and from a thorough study of the drawing the completed tool in operation can be mentally pictured. The complete understanding of the job at hand is absolutely essential before a cut is made on any piece of steel, for the very nature of the work governs largely which piece should be made first. It is better to spend a whole day, if necessary, in studying the drawing of a complicated tool than it is to have only a vague idea as to the working principle, for more often it will be found that, due to lack of thoroughly understanding the mechanism, several days' time is lost on a spoiled piece of work.

It is the importance of understanding the working of the machine that emphasizes the necessity of every tool-designer and die-maker being an expert mechanic.

## BLANKING AND SHEARING TYPES

## MAKING SIMPLE PUNCH AND DIE

**Size Factor.** In Fig. 306 of Tool-Making, Part III, are shown a blanking punch and die for use on heavy stock such as boiler plates. In a simple tool of this character it is immaterial which part is made first. But, should this same type of tool be required for piercing a small hole in heavy stock, the tendency would be to spring the slender punch, and, therefore, in such a case, the punch should be supported and guided by the stripper. Assuming that the punch is of  $\frac{1}{4}$ -inch diameter and is to pierce hard rolled stock  $\frac{1}{8}$  inch thick, the first step is to find the difference in diameters between the punch and the die.

**Clearance.** The rule for clearance is to multiply the thickness of stock in thousandths of an inch by .06; the answer being the difference in thousandths of an

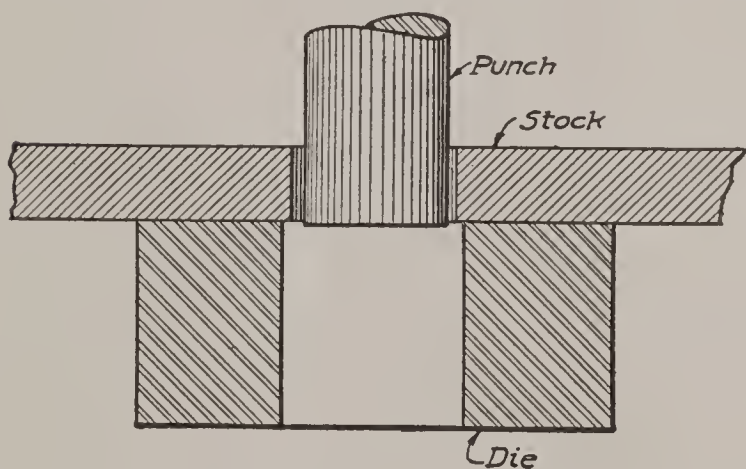


Fig. 1. Section of Die in Which Soft Stock Is Used

inch between the punch and the die.

Whether to increase the size of the die or to decrease the size of the punch depends upon the nature of the stock and whether the piece punched out must be of a certain

diameter or whether the diameter of the hole must be maintained. If the blank or piece punched out must be of a certain diameter, say .250 inch, then the die is made .250 inch, whereas, if the hole pierced is to be maintained .250 inch, then the punch is made .250 inch in diameter, and the clearance or difference between the punch and the die is obtained by increasing the size of the die. This is only essential, however, where the diameter of the hole or of the blank is to be maintained in thousandths of an inch.

**Resistance of Sheets.** When punching holes in sheet metal, the actual diameter of the blank, using the same die and punch, varies with the temper of the stock. For instance, on hard rolled stock the blank would break somewhere between the diameter of the punch and that of the die as exaggerated in Fig. 1. This is more

noticeable on heavy stock as the thick stock is stiff enough to withstand the pressure of the punch. If soft stock were used in a die as in Fig. 1, the stock would bend down between the punch and the die, causing a heavy burr on both the blank and the hole. A tight-fitting punch and die also causes heavy burrs on both hole and blank, when punching thick stock.

*Binding.* The main reason why a difference in the diameters of punch and die for piercing thick stock is necessary is to prevent breaking the punch. If a punch that snugly fits the die were used to pierce  $\frac{1}{4}$ -inch stock, the stock would be such a tight fit on the punch that it would be hard to strip the stock from the punch. Again, the severe rubbing of the punch as it passes through the stock would cause the punch to roughen, or, to use the shop term, to pick up, which causes the stock to stick to the punch, and which is one cause of the punch breaking.

Another cause of breaking, and one which the die-maker must guard against, is when the underside of the stripper, where the stock comes in contact with it in stripping, is not parallel with the die, or rather is not at right angles with the travel of the punch. It is readily seen that, if  $\frac{1}{4}$ -inch stock is snugly gripping a small punch and the stock comes in contact with the underside of a stripper plate which is on an angle, the stock is going to adjust itself to the surface of the stripper, which will snap off the end of the punch.

*Guiding.* Following the rule for clearance given above, we find the difference between the punch and the die to be .0075 inch, and, assuming that the punch is of small diameter, it now becomes important which part is made first, as the punch should be guided and supported. The term guided, when applied to a punch attached to the ram of a power press that travels in a positive channel, appears at first glance to be a misnomer, but any unevenness of the stock surface, such as caused by a slight kink in the stock or even by a piece of foreign substance on the stock, causes the punch to be deflected from its line of travel, resulting in a broken punch.

**Sequence of Operations.** *Making Die Bushing.* The sequence of operations for one good method of making the punch and die, Fig. 2, is to cut off a piece of round tool steel for the bushing *a*, Fig. 2, say 2 inches longer than desired, and, gripping the steel in a lathe chuck, to rough-drill the hole to within, say,  $\frac{1}{32}$  inch of size,

then to turn the outside diameter to the desired dimension, and finally to bore the hole to the desired size. Boring and turning at the same setting insures concentricity of the hole and the outside, providing, however, that one diameter is not finished before starting to machine the other diameter. For instance, if the outside were turned to exactly the right diameter, then the hole spotted, drilled, and bored, the pressure of spotting and drilling might cause the rod to spring or to shift in the chuck, resulting in the finished hole being eccentric with the outside. The tool-maker must constantly guard against any element of chance.

After both diameters are obtained, the bushing is cut from the rod, using a cutting-off tool in the tool post of the lathe. The clear-

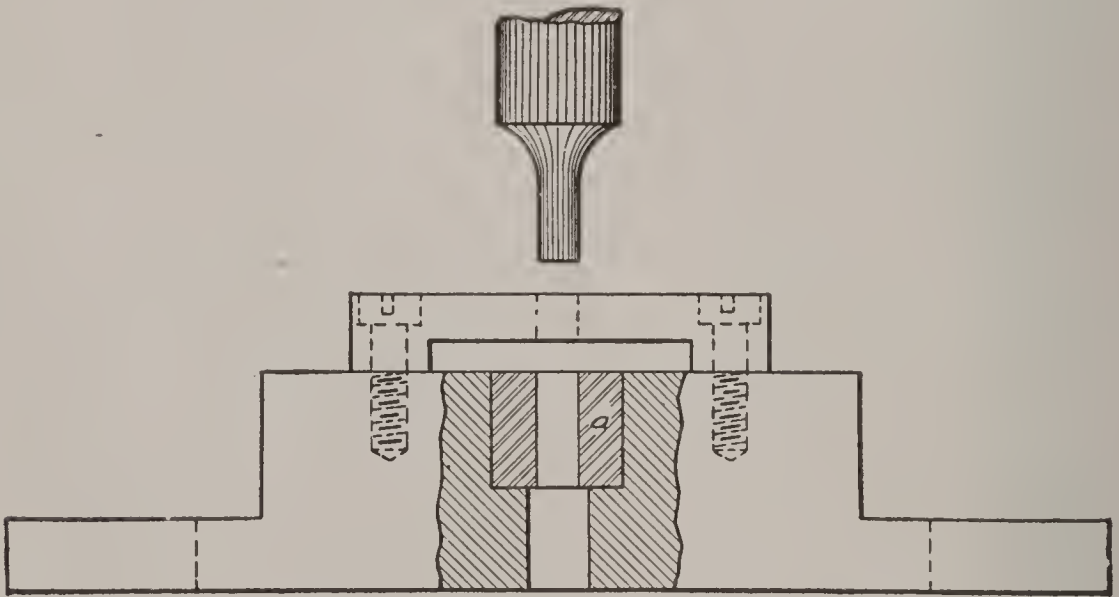


Fig. 2. Punch and Die Showing Use of Die Bushing

ance in the bushing can be bored by setting the slide rest at the desired angle, say  $\frac{1}{2}$  of a degree—the shop term for expressing  $0^\circ 30'$ . If a taper reamer is employed, we have no assurance that the finished taper hole will be concentric with the outside, as the reamer can be started on an angle with the hole. The bushing is now hardened and drawn to a dark straw color.

*Making Die Shoe.* The next step is to plane the bottom of the die shoe. As the top and bottom surfaces of die shoes must be parallel, it is obvious that we must hold the die shoe by clamping it to the bed of a shaper or on the faceplate of a lathe. If gripped by its rough sides in a shaper vise, difficulty would be experienced in obtaining parallel surfaces.

*Alignment of Stripper.* After machining the top surface of the shoe, the bushing is inserted. At this point is where the die-maker must be careful on this particular job. The haphazard trust-to-chance method is to drill and counterbore the hole for bushing, drive in the bushing, attach the stripper by means of screws, then put the hole in the stripper by transferring through the hole in the bushing.

The more accurate and workmanlike method is to make the punch after machining the top surface of the shoe, then to make and attach the stripper to the die shoe by screws and well fitting dowel pins. Lay out and prickpunch on the stripper face approximately the desired location for the die hole, and strap the die shoe to the faceplate of the lathe. It should be remembered that whenever any work is clamped to the faceplate of any machine, the faceplate with the work attached is always to be revolved one complete revolution by hand to make sure that projecting corners of the work clear all parts of the machine; this will prevent many accidents.

Indicate the prickpunch mark to be comparatively true. The shop phrase *indicate* means to place the contact point of a test indicator, as shown in Fig. 3, against the work, and, when the work is properly located, the indicating pointer will not deviate from a graduation on the arc. Graduations on test indicators are usually so spaced that their intervals represent one one-thousandth of an inch each. If the indicating pointer moves two graduations during one complete turn of revolving work, it means that the work is actually out of true only one one-thousandth.

Spot the stripper and drill the hole clear through both the stripper and the die shoe. Then bore the hole in the stripper to fit that portion of the punch that enters the stripper. The stripper is now removed, but the die shoe is not disturbed, and the hole for the bushing is bored in the die shoe to a driving fit. The reasons for boring the stripper are many. First, we can make the hole fit the punch, which would not be so easy if the hole in the stripper were drilled—the drill being guided by the hole in the die which would be somewhat larger than the drill. It is obvious that the hole in the stripper might not be directly in line with the hole in the bushing. Again, by drilling through the die shoe the shoe would rest either on the screw heads on the stripper, or on the face of the stripper, or on the parallels, any one of which may cause the drill

to pass through the stripper on an angle. Granting that the parallels, or whatever is used, will insure the bottom of the die shoe

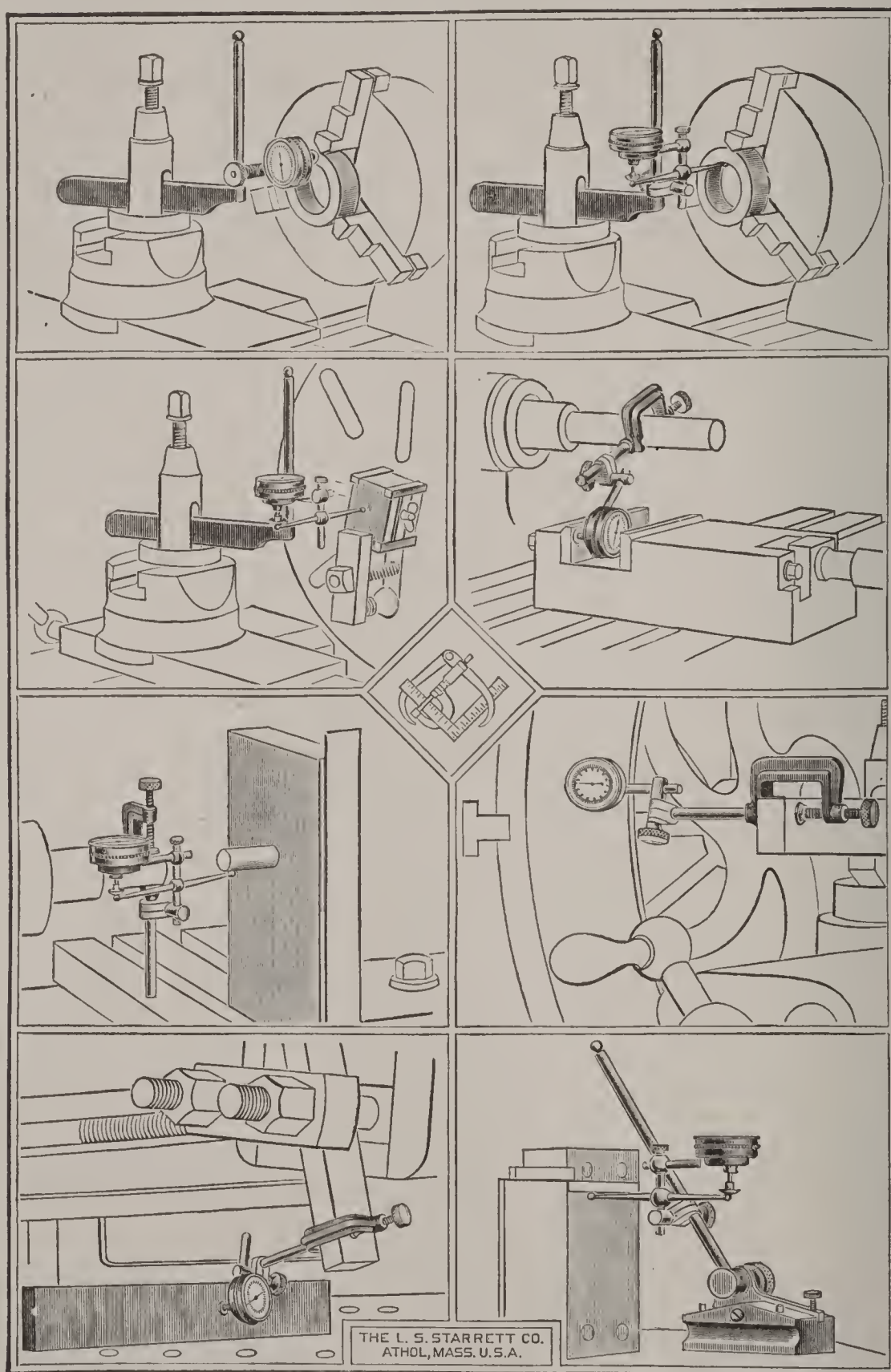


Fig. 3. Various Positions of Test Indicator in Shop Work  
*Courtesy of L. S. Starrett Company, Athol, Massachusetts*

resting parallel with the table of the drill press, it does not follow that the table of a much abused drill press is at right angles with the travel of the drill-press spindle, and the hole that is drilled and

reamed through the stripper may be at an angle, so that when the die is set up for work in the press the punch will have to spring every time it passes through the stripper, which will eventually cause breakage of the punch.

It is attention to these apparently unimportant details that distinguishes the master workman from the ne'r-do-well class. At first glance, the punch and die shown in Fig. 306, Tool-Making, Part III, looks insignificant—all that is necessary apparently being simply to turn up a round piece, bore out a round hole, attach a strip across the top, and the die is complete—and on some classes of work this is true, but that same simple die may be called upon to perform work that requires greater care in die-making than the haphazard method.

#### Irregular Shapes

**Question of Steel.** *Sheet Stock.* Fig. 307, Tool-Making, Part III, shows that type of die known as an irregularly shaped blanking die. When making this die the die-maker should follow the blue print absolutely, unless, of course, he discovers an apparent mistake, in which case the foreman's attention should be called to the fact. If a blue print is furnished, the dimensions and the horizontal angle at which the die is to be laid out appear on the print, but if no drawing is furnished, the die-maker should first of all ascertain what width and what thickness of stock is ordered for the job, as the width of the stock governs the angle at which the die must be laid out on the die block.

The angle of the die in relation to the die block is very important, if the blank is to have subsequent bending operations, due to the fact that in rolling the sheet stock there is an actual grain, and bending the blank with or across the grain is almost analogous to bending wood. A piece of sheet stock can be bent at right angles having a sharp corner, if the bend comes crosswise of the grain, but if the bend is made lengthwise of the strip, the stock will break. Therefore, a die-maker, knowing this, should not proceed with a die unless he has full information. This is another instance of eliminating every element of chance or, that other bugaboo, of taking things for granted.

*Die Stock.* Assuming that the blank is to remain flat and that the sheet stock is ordered just wide enough to punch one blank from

the strip, the first move is to select the die steel, for it is absolutely essential when hardening the die to know what brand of steel the die is made from. Some makes of tool steel are more expensive than others, and certain makes are made to harden in oil which prevents distortion to a great extent, while if the oil hardening steel were hardened in water, the die would crack. On plain dies, such as Fig. 4, any good grade of carbon steel which is lower in cost will answer, as there are no delicate points on the die to distort or to present chances of cracking. If there is no distinguishing mark on the steel, it is best to cut a small piece from the bar, drill several holes in it, and use it as a test spiece, hardening it in water.

**Preparing Die Block.** Having ascertained the brand of steel, the block is cut from the bar, and the first surface to be planed or milled should be the widest surface; this giving a broad bearing for the machined surface to rest against the solid jaw of the vise. The edge is next machined, then keeping the broad machined surface against the solid jaw, the block is turned so that the edge just machined rests on the bottom of the vise. We now have two machined surfaces resting on two machined surfaces of the vise, and the other edge is machined. A pair of parallels are placed on the bottom of the vise, and the broad finished surface is placed on the parallels, which causes the two machined edges to come in contact with the vise jaws. We now have three machined surfaces to position the block when machining the other broad surface. At least one end of the die block should be machined at right angles, or to use the shop term, machined square with the edges. The object in machining the end is to aid later in laying out.

*Working Face.* Whichever side is to be used for the top or working face of the die should have at least  $\frac{1}{16}$  inch of stock removed, due to the fact that in hot rolling tool steel the outer surface becomes oxidized and is decarbonized to a certain extent, and, unless enough stock is removed to get under this burned surface, the die may cause trouble in hardening as the top surface may be soft in spots, in connection with which, if the die is rehardened in an attempt to obtain an entire hard surface, the repeated hardenings invariably produce cracks in the die. If a die, after the first hardening, should appear soft in spots, it would be better to draw the temper and to grind, say,  $\frac{1}{32}$  inch from the top surface in order to remove all burned

metal. If the decarbonized surface caused the soft spots, the entire surface of the die would be hard after grinding, and rehardening would be unnecessary. Also, prior to laying out the die, the top surface of the die block should be machined very smooth and should

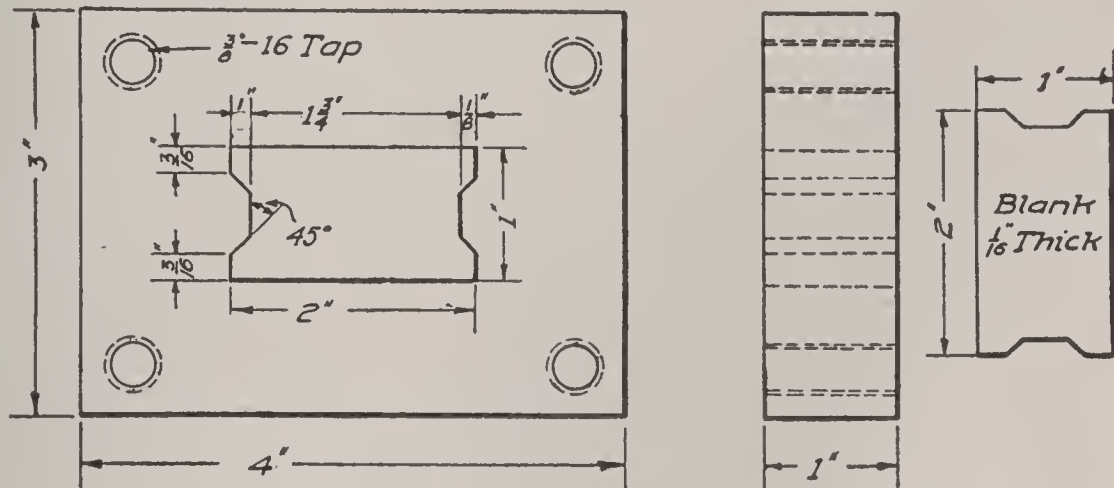


Fig. 4. Drawing of Piece to Be Prepared

be further smoothed with emery cloth. Instead of laying the grain one way when using emery cloth, it is better to polish with a circular motion, as lines scribed on the die are more pronounced over circular emery marks than over straight ones. When nicely smoothed

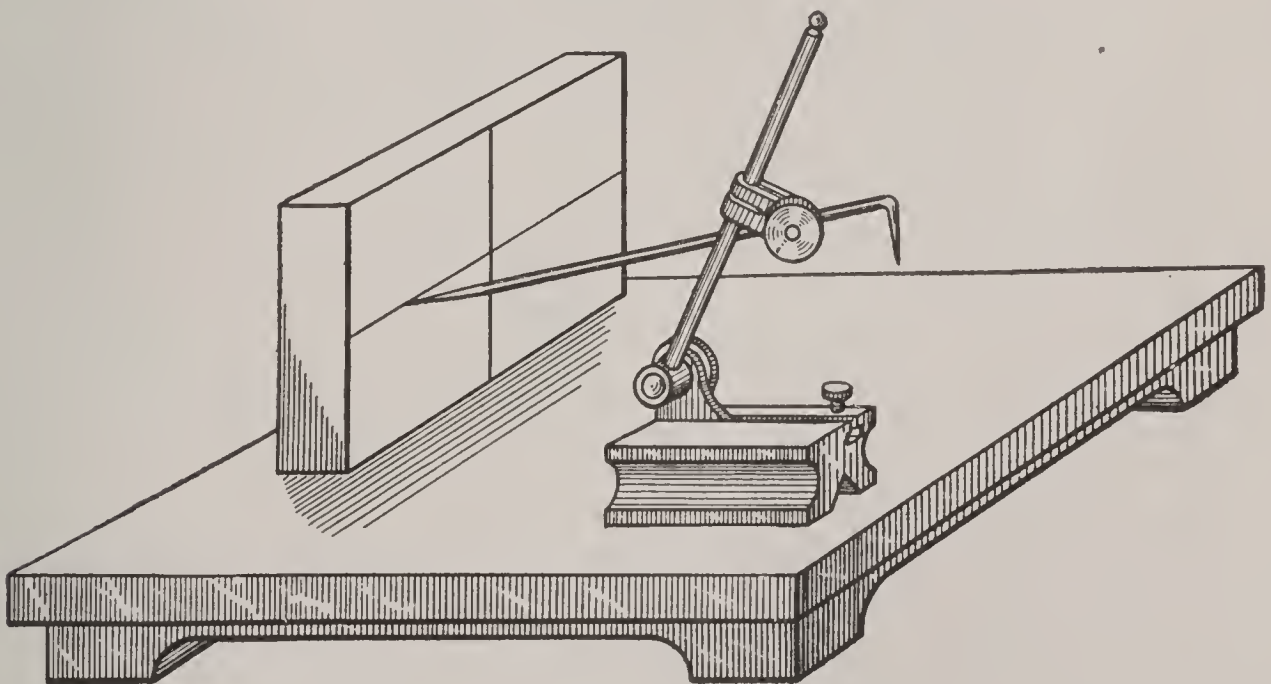


Fig. 5. Scribing Center Lines on Block

the surface should not be touched, especially with the fingers, as grease marks interfere with the proper bluing of the surface.

The block is now placed, polished side up, over a forge and heated slowly until a deep blue appears on the surface, at which point the color is set by quenching, preferably in oil. A scribed line is more

pronounced on a blue surface than if a copper-sulphate blue-vitriol solution is used, and another objection to the coppered surface is that it peels off when drilling and filing the die, which removes the scribed lines. The die block is now ready to lay out.

**Laying Out Die.** If a templet or model blank is furnished from which to make the die, then the clamp shown in Fig. 332, Tool-Making, Part III, is used to securely hold the templet on the face of the die block while the outline is traced with a fine sharp pointed scriber. If, however, a drawing, Fig. 4, of the piece is furnished, the first step is to scribe center lines on the block as in Fig. 5, in

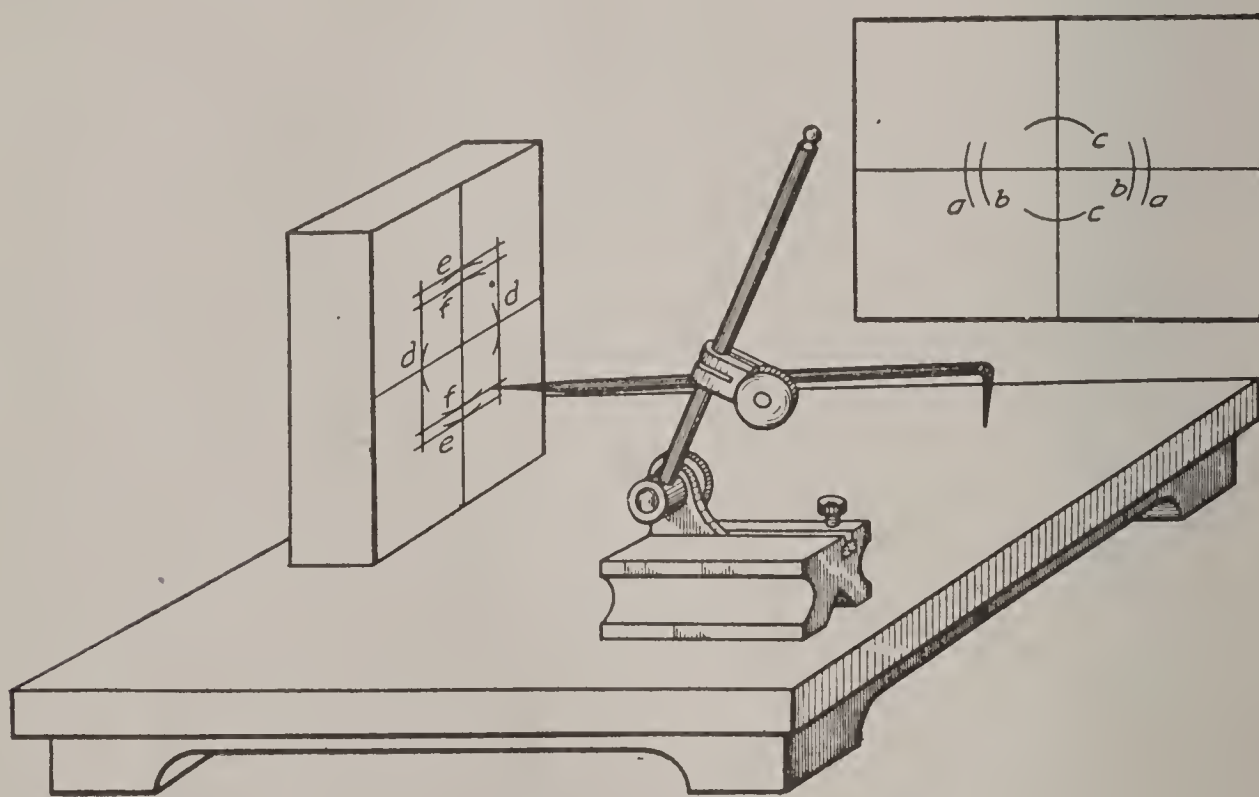


Fig. 6. Method of Scribing Center Lines

order to transfer the outline, as shown on the drawing, to the face of the die.

Referring to the drawing, Fig. 4, we note that the overall length is 2 inches and the width is 1 inch. A fine prickpunch mark is placed at the intersection of the lines, the divider points are set 1 inch apart, and a section of a circle is scribed at each end as at *a*, Fig. 6, and, by again referring to the drawing, it is noted that the inside dimension is  $1\frac{3}{4}$  inches. The dividers are set at one-half this— $\frac{7}{8}$  inch—and the lines *bb* are scribed. The width being 1 inch, the dividers are set at  $\frac{1}{2}$  inch and the lines *cc* are scribed. The lines *dd*, *ee*, and *ff* are now scribed, using the surface gage or scratch block as at *B*, Fig. 6. This is why one end of the die block was

machined at right angles to the edges when machining. A square can be used instead of the surface gage, but it is not quite as handy. The angle lines are scribed by setting the protractor at 45 degrees and scribing along the blade, as at Fig. 7.

### Shaping of Die.

*Roughing Out.* If a die filing machine, Fig. 319, Tool-Making, Part III, is at hand, a narrow hack-saw blade is placed

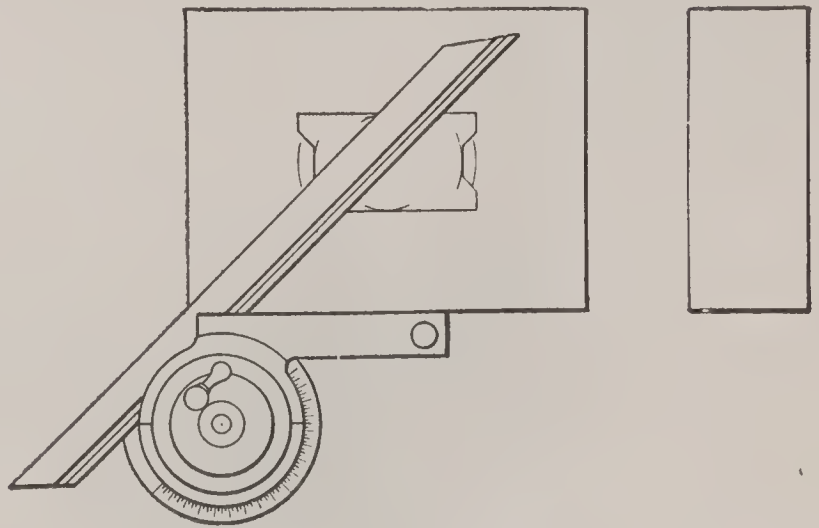


Fig. 7. Scribing Lines by Means of Protractor

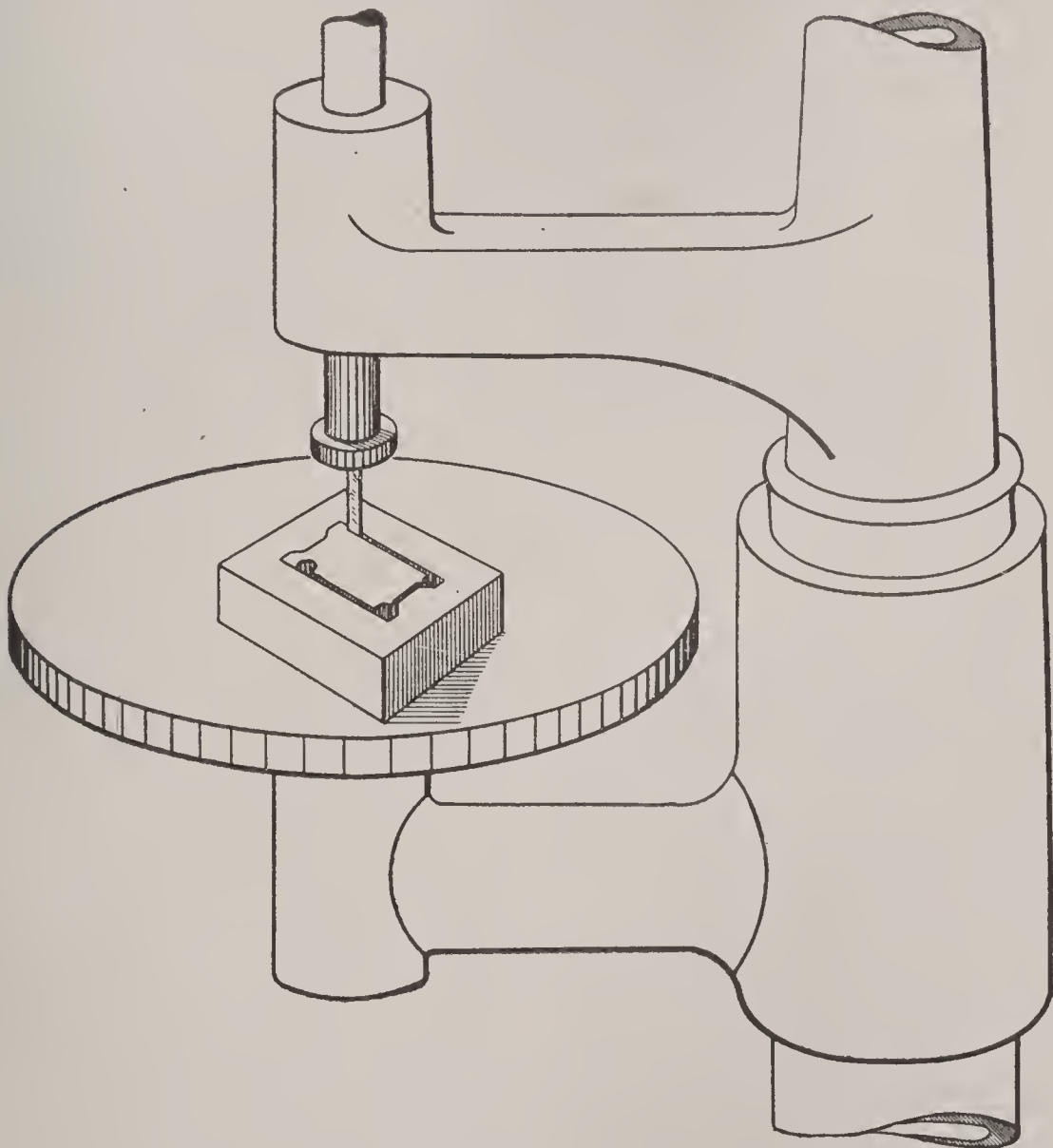


Fig. 8. Sawing Out Block with Die Filing Machine

through the hole drilled in the corner of the die, and the blade with teeth pointing downward is secured in place of the file, as

in Fig. 8. By tilting the table the desired angle the piece in the center of the die can be sawed out very close to the line, with the desired clearance, which leaves very little to file. If a die filing machine is not used, the center piece is removed by drilling a series of small holes just inside the line and by cutting out the

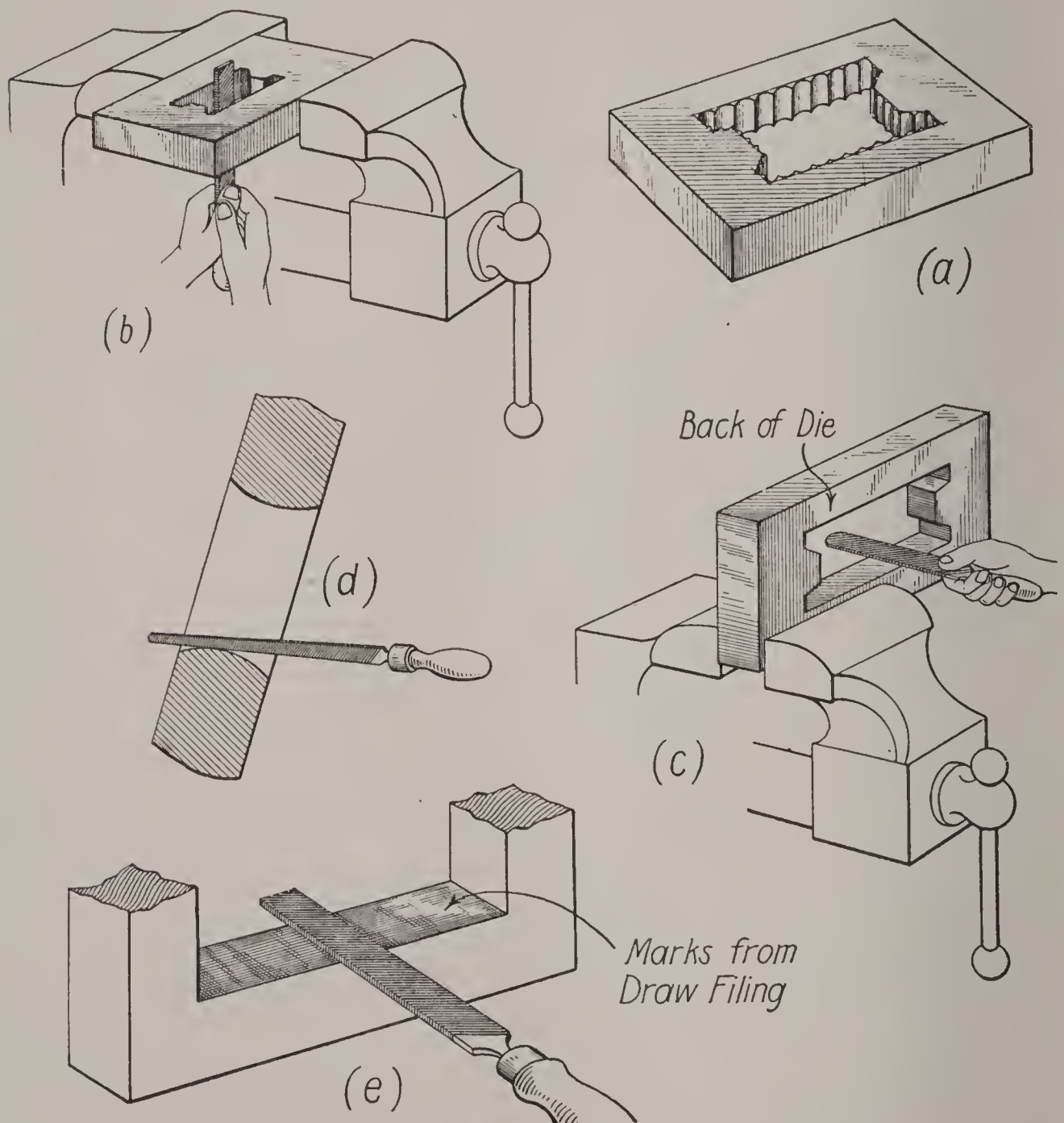


Fig. 9. Die Block in Various Stages of Completion

web between the holes with a broach, as described in connection with Fig. 312, Tool-Making, Part III. After the broach has been driven nearly half way through from both sides of the die, the center piece can be forced out. The die then looks as in *a*, Fig. 9.

The webs between the drilled holes can be removed easier and quicker by means of a cold chisel and hammer than by filing, but

great care must be exercised when using a chisel, for there is danger of cutting too deeply. After the greater part of the webs are removed, the die is gripped in the vise in a horizontal position, top side up, and with a coarse file the remaining webs are removed by filing up and down as indicated in *b*, Fig. 9. Filing in this position has several advantages, but for final-filing to line and to straighten the filed surface better results are obtained by filing crosswise as in *c*, Fig. 9.

The most expert die-makers cannot file a die in one direction without producing a slightly rounded surface as exaggerated in *d*, Fig. 9. As the line is approached in filing, the filed surface should be draw-filed frequently. By filing crosswise, then draw-filing in the opposite direction, the file marks or grain is laid lengthwise of

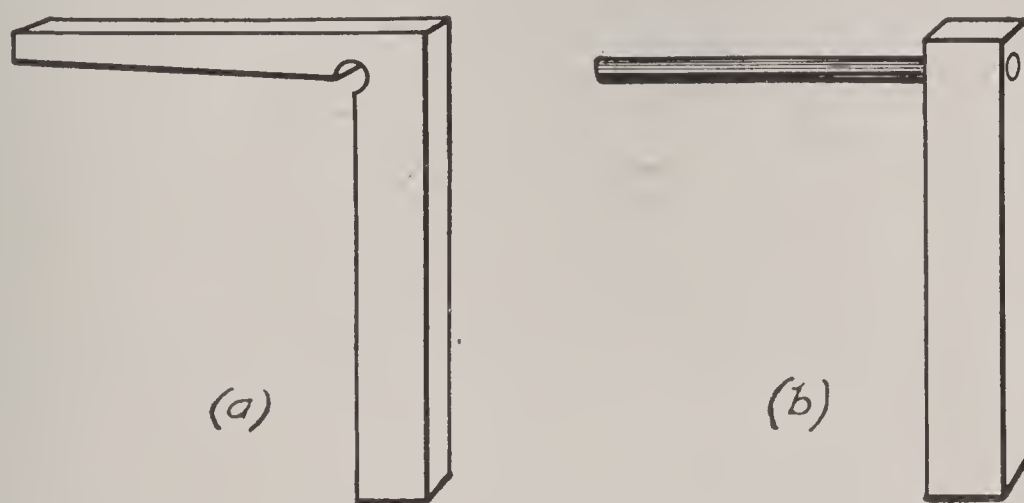


Fig. 10. Die Square

the die, so that as cross-filing is continued the marks lengthwise serve as a guide as to whether the die is being filed straight or not, as in *e*, Fig. 9.

*Clearance.* As soon as the webs between the drilled places are entirely removed, the clearance of the die should be started. This is aided by using a narrow-blade die square of the proper angle, Fig. 10. These squares are made by die-makers by filing from  $\frac{1}{16}$ -inch sheet steel, and the blades are about  $1\frac{1}{2}$  inches long. Some use a small block with a straight rod inserted as at *b*, Fig. 10. When the opening is filed so that the scribed outline on the face of the die is partly filed away, the filed surface through the die should be carefully tested with a knife straightedge to make sure that the cutting edge or the top of the opening is not wider than the opening midway

through the die. By using a fine file or a flat scraper, the filed surface can be made very straight.

*Compensating for Bulging.* If the shop practice is to have only  $\frac{1}{2}$  of a degree clearance, it means that the opening through the die will have almost parallel walls. Attention must be paid to these walls if the die is somewhat heavy or thick, as there is a bulging effect in the opening when the die is hardened, as shown at *a*, Fig. 11. This is probably caused by rapid contraction of the exterior surfaces of the die when immersed in the bath, and this contraction compresses on a comparatively soft interior, as the interior is red hot. To guard against the bulging, the walls of die should be scraped

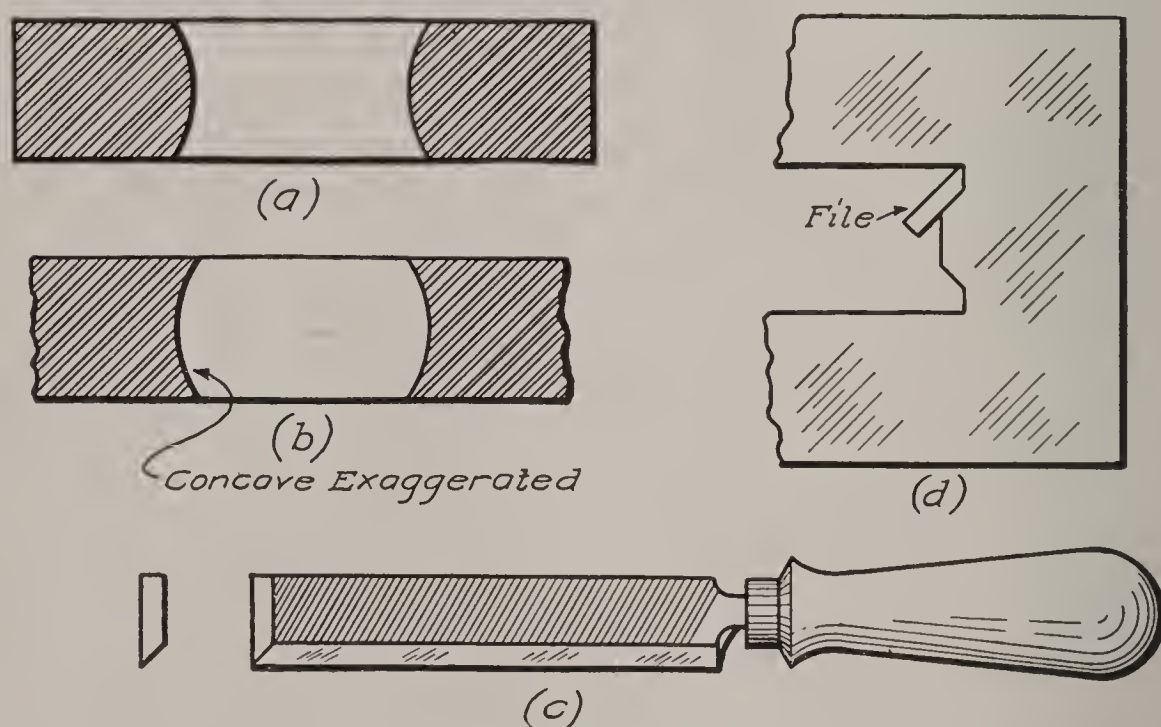


Fig. 11. Sketches Showing Method of Compensating for Bulging and of Filing Corners

slightly concave, as shown at *b*, Fig. 11. It is readily seen that, if the walls are almost parallel and then they bulge toward each other during the hardening process, a blank would not pass through the die without distortion of the blank.

*Filing Corners.* When filing the corners of any die, the file must have a smooth edge in order to preserve the corner. Again, when filing an angular surface as on the die in question, it is good practice to grind the file as at *c*, Fig. 11; the smooth part sliding on the straight part of the die. If the file is not ground to suit the angle, the file constantly slides down the angle, and the corner of the file mars the finished flat surface at the end of the die. The die files, as

purchased, seldom are of the right size or shape, and the die-maker must grind the file to suit the job.

*Tapping.* Referring to the drawing of the die, it is noted that there must be four holes drilled and tapped for  $\frac{3}{8}$ —16 screws. As the die is of tool steel and also since it is to be hardened, a full thread is not necessary, and a  $\frac{5}{16}$ -inch drill will leave ample stock. After all holes are drilled and tapped, the die should be carefully checked with the drawing to make sure that all holes are in the die.

**Hardening of Die.** The next step is to harden the die. The hardness of a die or of any piece of tool steel depends largely upon the degree of heat to which the steel is heated, and upon the rapidity of cooling. For instance, three pieces of carbon steel, Nos. 1, 2, and 3, are all heated to the same degree of temperature. Piece No. 1, immersed in a bath of oil, would not be as hard as piece No. 2, immersed in water. If piece No. 3 were dipped in a bath of mercury and allowed to cool in the bath, the piece would be harder than those dipped in oil or in water. Mercury has a higher heat conductivity, therefore the heat in the die is dissipated more rapidly with such a bath, causing a greater hardness. Starting with the three pieces at same temperature and obtaining three degrees of hardness shows that it is the bath that plays an important part.

*Corner Protection.* Knowing that the dissipation of heat in the die plays a prominent part in hardening, we must then guard against the effect of holes in the corners of the die. If the die were dipped with the tapped holes open, the water or bath of course would fill the holes, and the heat would be conducted away faster from the corners than if the holes were not there. Therefore, it is good practice to fill the screw holes, or any hole that comes near a corner, full of asbestos before heating the die; this eliminates some of the chances of cracking. If the holes were left open and a free circulation of water passed through the holes carrying away heat from the die, and the outside surface of the corner were also in contact with or immersed in water, the contraction of the corner would be so much more rapid than that of the main portion of the die that, when the main portion continued to contract, it would cause a tremendous strain between the portion contracted and the portion contracting, which would result in a crack. The corners invariably drop off if not plugged with asbestos. Fire clay is sometimes used,

but it is not good practice, for the water in the clay is driven off when heating the die and the clay shrinks and drops out of the hole.

*Tempering.* Assuming that the die is ready to harden and having the screw holes plugged—with a soft machine screw if desired—the die is heated slowly and evenly in a muffled fire preferably. A blast such as a black smut forge would cause uneven heating of the die, which means uneven expansion. If either an open forge or a muffle furnace is used, the position of the die should be constantly changed to insure even heating, and the face of the die should be up. When an even temperature of the desired degree is obtained—varying with different makes of steel—the die is gripped by tongs, plunged into the bath, and moved slightly up and down, keeping it fully submerged at all times.

The die should not be allowed to remain in the bath, however, until it becomes cold, because some parts of the die will contract faster than others. When the violent vibration on the tongs ceases, the die should be removed and plunged into an oil bath as quickly as possible. This is done to allow the heat from the heavier portions to flow into the parts that are cooler, causing a more even contraction. The die should be removed from the oil bath before the die is cold, it should be drawn to the desired temper immediately and, to allow it to cool slowly, should be set on some material which is of low heat-conductivity. If a hardened die, while hot, were set on a cold mass of steel, the chances are that cracks in the die would result.

**Finishing of Die.** After the die is thoroughly cool, the oil and scale are removed, and the face that is most level is placed against the grinder bed and the other face is ground. The bottom of the die need only be ground until a true surface is obtained, but the top or cutting surface should have several cuts taken across to remove any burned metal that may have been caused in hardening and also to insure the cutting edge being keen its entire length.

**Laying Out Punch.** The next step is to make the punch. Assuming that the blanking punch has been machined, the bottom or cutting surface is blued in, the same as the die, the punch is clamped to the face of the die as at Fig. 12, and the outline of the die is transferred to the face of the punch. A very slender and sharp-pointed scriber must be used, and after the entire outline is scribed, the line

must be inspected carefully before the clamp is removed. It is easy to make an error in transferring the outline, as the die is quite thick and the scribe must of necessity be tapering, and the largest diameter of the scribe can rest against the die instead of the point of the scribe being in contact with the cutting edge of the die.

If the die has narrow places where it is not possible to scribe the line, then the surface of the punch is coated with solder and machined level, and the outline of die is transferred by forcing the solder into the die.

**Forming of Punch. Shearing Method.** The punch is now gripped by the shank in the chuck of a milling machine—the shank having been turned on the punch for two reasons: to facilitate milling the punch to shape; and to act as a heavy pilot to stiffen the punch on the punch plate. After milling to within, say,  $\frac{1}{64}$  inch of the line, the punch is removed and the entire cutting edge of the punch is beveled slightly, and, placing the punch in the die opening, the punch is forced in far enough to obtain the exact outline of die. This operation is called *shearing the punch*.

The punch can then be replaced in the chuck of the milling machine, and by skillful workmanship all surplus metal can be milled away, leaving only a small amount of hand work necessary to complete the punch. If the punch is milled after it has been sheared in the die, a narrow cutter must be used to remove the small and surplus stock. A safer way for the beginner—in fact, many experienced die-makers pursue this method—is to chip the stock away, shear the punch again, and the stock that the cutting of the die causes to curl up is again chipped and scraped away, then repeating the operation until the punch is fitted the desired depth.

One point that is essential when shearing a punch in the die is to make sure that the punch enters at right angles with the face of

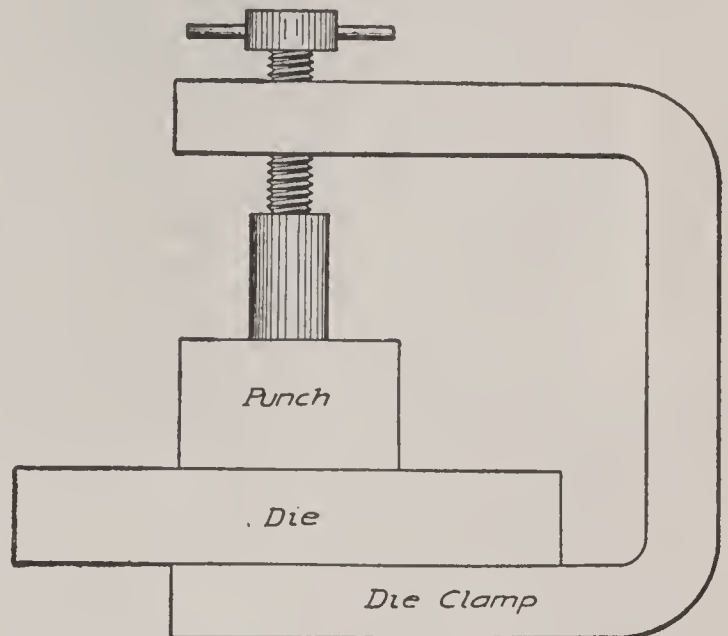


Fig. 12. Laying Out Punch

the die and also that the punch cannot tilt when being withdrawn. Any tilting when withdrawing will surely break off the weak corners of the die. Therefore, it is best to secure the punch in the ram of a press and to fasten the die securely to the bed when shearing.

Punches and dies having no weak corners or points can be sheared by forcing the punch in the vise but the edge of the punch will be rounded off when driving out the punch, if great care is not exercised, as one end will invariably drive out ahead of the other.

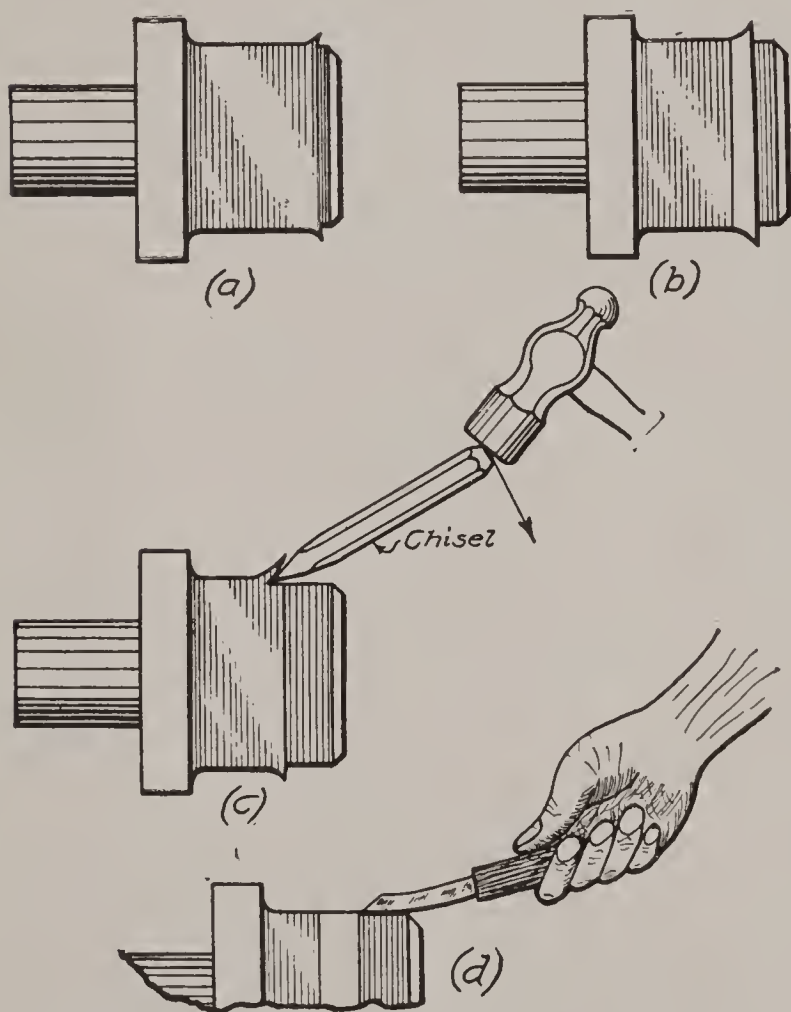


Fig. 13. Chipping Away Surplus Stock on Punch

In Fig. 13 at *a*, *b*, and *c* the punch is shown as it appears at the first, second, and third shears. The punch should not be forced in more than  $\frac{1}{8}$  inch at a time, as the die does not actually cut the metal away, but crowds it out, and, after a certain amount of stock is banked up on the punch by the crowding or pushing action, the stock tears away from the punch and deep spots will be torn in the punch that are below the size of the die. For chipping away the surplus stock, the chisel

should be ground so that it does not have a tendency to dig in, and the chisel should be struck as shown at *c*, Fig. 13.

After each shearing operation and chiseling away of stock the surface is smoothed by scraping, *d*, Fig. 13, and by filing. Only the point or end of the file must be used, or else the cutting edge of the punch will be filed tapering or too small. The entire surface of the sides of punch must be reduced to less than the size of the die, governed by the thickness of metal to be punched, and the surfaces should be made smooth.

*Finishing.* If the punch is to be secured to the punch plate by screws, the holes are drilled and tapped in the punch by transferring the holes from the punch plate.

The punch is now gripped by its shank in a lathe chuck and the beveled edge is faced off, leaving a sharp corner or cutting edge, after which the punch is hardened. Punches are not made as hard as dies, and a deep dark straw color or even purple proves satisfactory for stock that is not tempered by heating and dipping. For punching thin soft metals—aluminum, copper, or brass—or paper, the punch is generally left soft, for there must be a close fit between

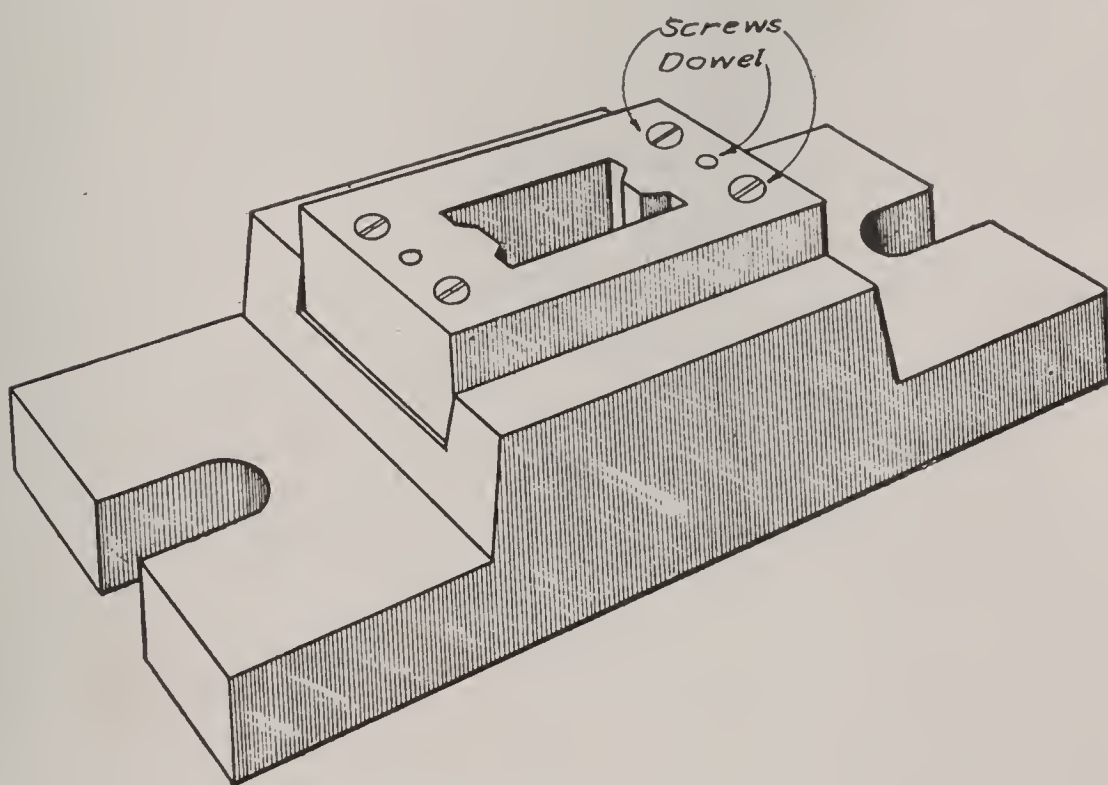


Fig. 14. Die Fitted Tight in Die Shoe

it and the die in punching thin stock, and when the punch becomes dull, which is caused by its rubbing through the material being punched, it can be upset or riveted slightly around the edge and sheared into the die without taking the punch from the press. This insures a perfect fit between the punch and the die which is essential on very thin stock.

After hardening, the punch is attached to the punch plate, and the cutting face of the punch is ground by resting the back of the punch plate against the bed of the grinder. This insures the face of the punch and the back face of the punch plate being parallel.

*Stripper.* The stripper is now fastened to the die without the guide strip *D*, Fig. 307, Tool-Making, Part III, so that the stripper

comes in contact with the face of the die. The outline of the die is now transferred to the stripper, and the stripper then is removed and the opening drilled and filled, much the same as for the die, except that the opening in the stripper is generally made somewhat larger on large blanking punches.

**Die Shoe.** The adjustable die shoes shown in Figs. 308, 309, 310, and 311, Tool-Making, Part III, are designed more for a jobbing shop where quick changes are made, that is, where only a few blanks of each kind are made at a time; but for continued daily production it is better to fit the die tight in a recess in the die shoe, as in Fig. 14, and to have a separate die shoe for each die. The first cost of making the die shoe for each die is soon wiped out by the saving of the pressman's time in changing the dies from one shoe to another.

### SUB-PRESS DIES

**Typical Features.** Plain blanking dies as described this far are of the simpler type and are used only where a variation in blanks is permissible, for any die that allows the blanks to pass clear through is given clearance, and each time the die is ground the die becomes larger. With sub-press dies—sometimes called compound dies—the outside diameter or size of blank does not change, as the dies are made without clearance, for the blank only enters the die about half the thickness of the stock being punched, then the blank is forced back into the strip.

Before entering upon the making of a sub-press die, it is well to thoroughly understand the working of this type of die which in some instances is quite complicated. The term *sub-press die* means that the punch and die are mounted in a sub-press, or, to make it plainer, the punch and die work within a frame which has a babbitted bearing to guide the plunger to which the blanking die and piercing punches are attached, and this frame or sub-press is in turn actuated by a power press.

Fig. 363, Tool-Making, Part III, is an excellent illustration of the working principle of sub-press construction in its simplest form. Bear in mind that this die is a sub-press in principle only. Referring to this illustration it is noted that the blanking die *A* is mounted on the upper portion, which is characteristic of all sub-press construction. The blanking punch *B* also contains the piercing die *C*,

and inside the blanking die *A* and surrounded by the upper stripper *E* is the piercing punch *D*. The lower stripper *F* surrounds the blanking punch.

*Operation.* In operation the stock is placed on top of stripper *F*, and as the upper portion descends blanking punch *B* enters blanking die *A*, causing stripper *E* to recede. At the same time that the blanking punch enters the die, piercing punch *D* enters piercing die *C* in the blanking punch. In fact, all parts interlock. The blank is forced into die *A*, and the

scrap punching passes down through hole *C*. As the upper section ascends or separates, strippers *E* and *F* move toward their original positions, due to spring pressure, just as fast as the upper section ascends. The result is that the blank is forced back into the strip by both strippers.

While the die shows only the principle and would blank a washer at each stroke, it can be readily seen that the blanking punch and die can be of any shape and

that a number of piercing punches may be employed. Any one of the sample punchings shown in Fig. 379, Tool-Making, Part III, is made at one stroke, and the clock plate shown has thirty-four separate piercing punches.

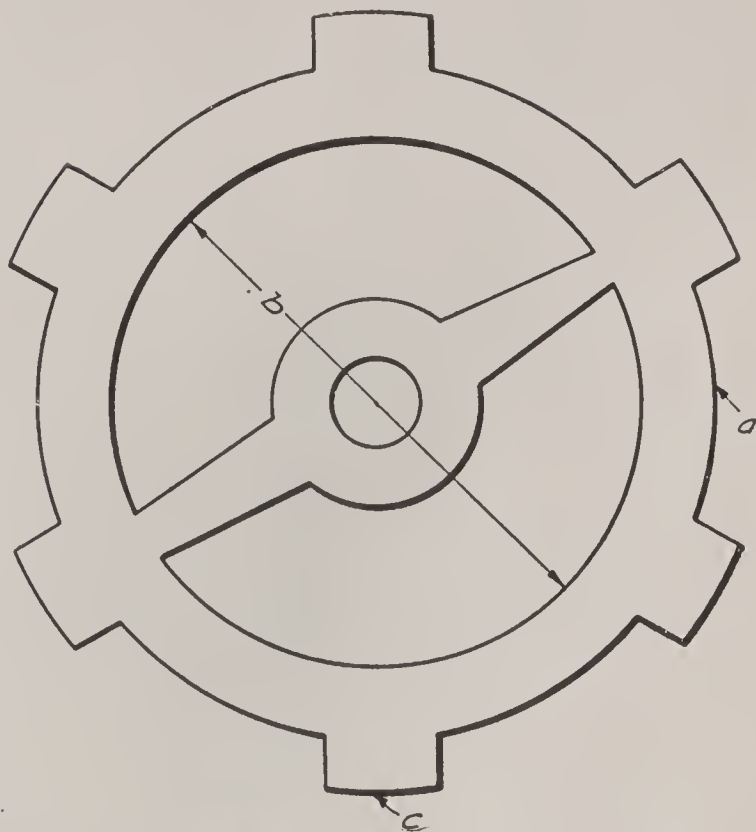


Fig. 15. Blank Produced by Sub-Press Die

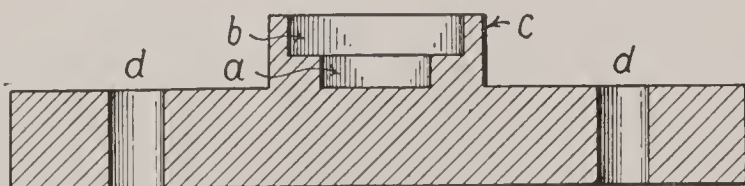
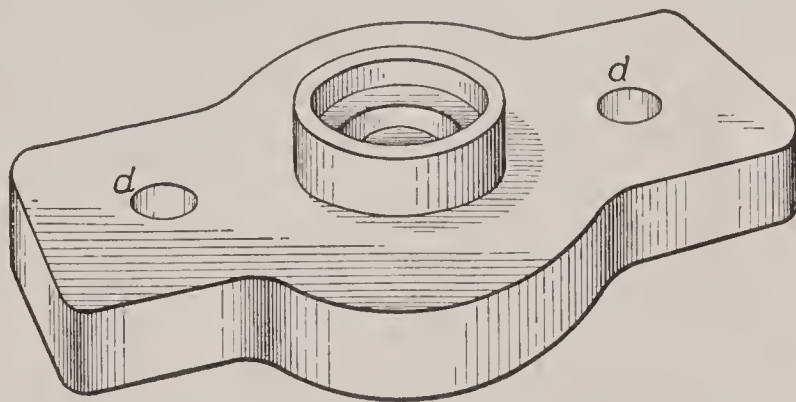


Fig. 16. Sub-Press Base

**Making Press Body.** To make a sub-press die to produce the blank shown in Fig. 15—the balance wheel of a clock—looks at first glance to be a difficult job, but in reality it is simple, and the die can be made without touching a file to it except to remove a few burrs. The sub-press base, Fig. 16, is made by first planing the bottom, then, strapping to a lathe faceplate, the top face is turned

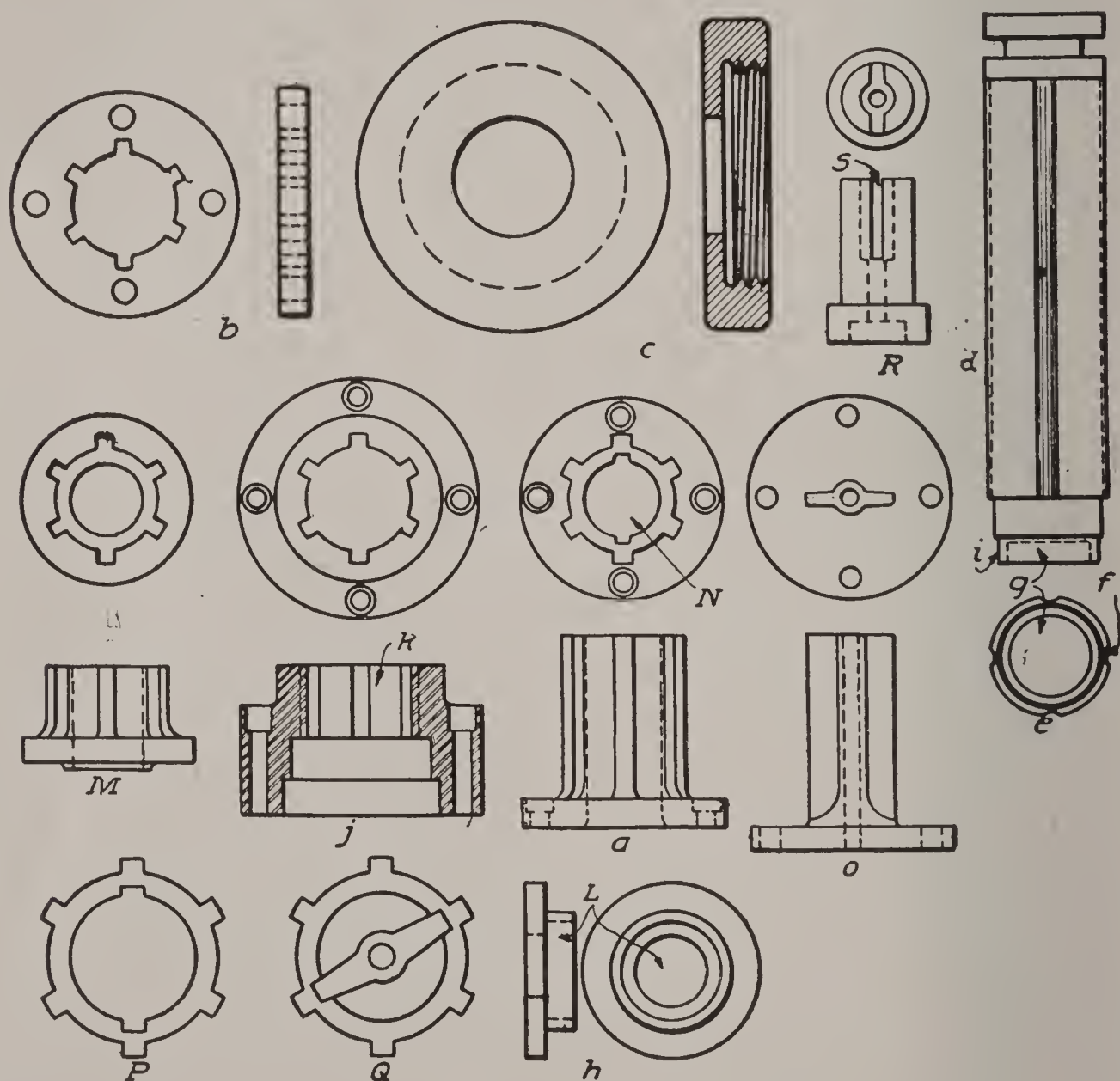


Fig. 17. Sub Press parts: *a*—Blanking Punch and Piercing Die; *b*—Lower Stripper; *c*—Press Frame Cap; *d*—Plunger; *h*—Punch Holder; *j*—Blanking Die; *M*—Upper Stripper; *o*—Crossbar Punch; *P*—Section of Blanking Punch; *Q*—Section of Assembled Blanking Punch; *R*—Piercing Punch

level and the recesses *ab* are bored. The recess *a*, Fig. 16, is the seat for the blanking punch *a*, Fig. 17, and the large recess *b*, Fig. 16, receives the lower stripper *b*, Fig. 17, for the blanking punch.

The frame *a'*, Fig. 18, is next machined by gripping the end *b* in a lathe chuck and facing off the bottom, and boring the recess to a good push fit for the outside of flange *c*. The inside of the frame

must be bored tapering, but not while gripped in chuck, for the frame is thin and that portion gripped is slightly distorted, and the inside it would not be round when the chuck pressure is released.

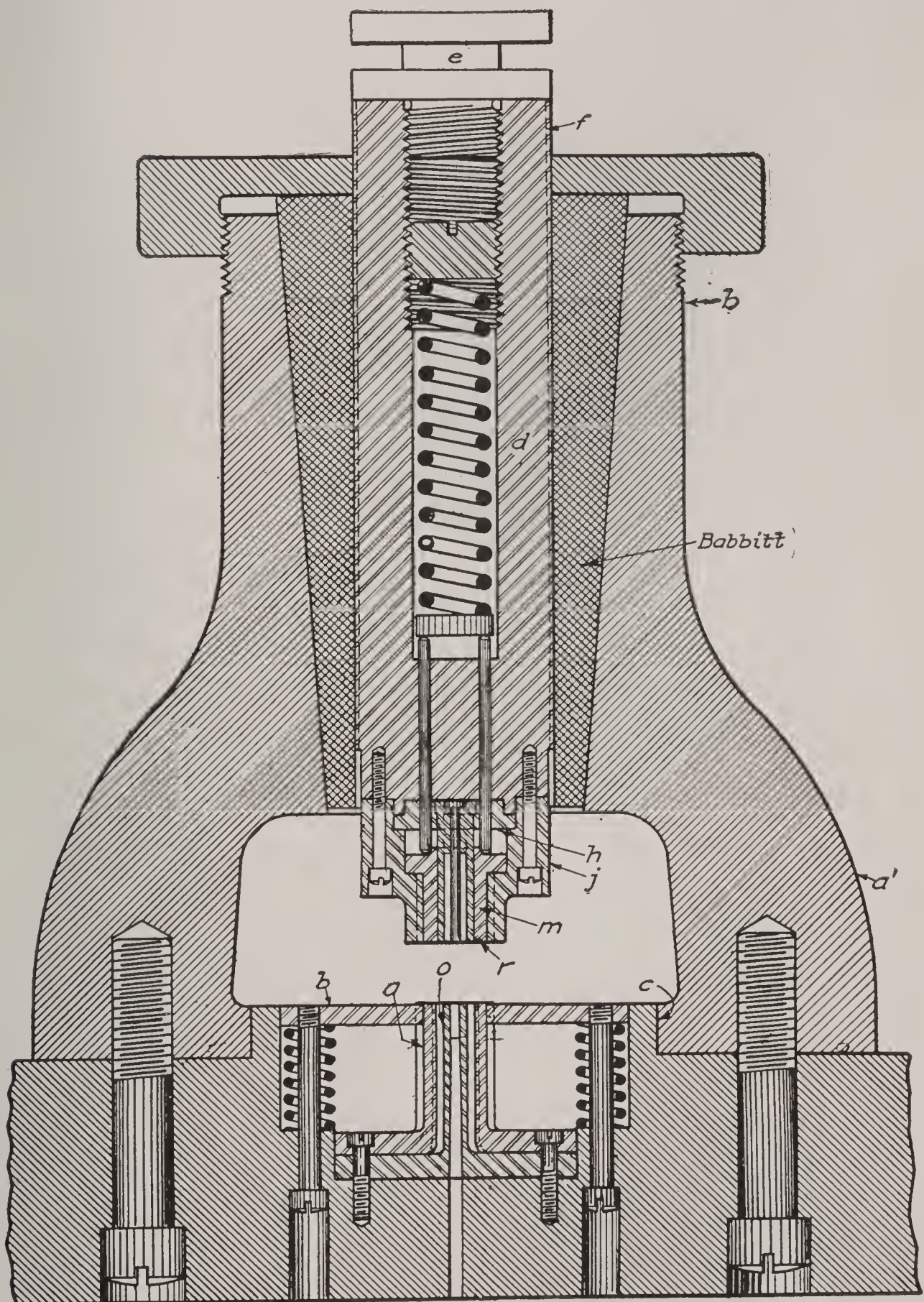


Fig. 18. Details of Sub-Press Punch and Die for Fig. 15

The base, Fig. 16, is now drilled as at *dd*, the frame is placed on the base, and the holes *dd* are transferred to the frame. The

holes in the frame are tapped, the frame is removed, and the holes are slightly countersunk to remove all burrs to insure the frames resting level on the base. The base is then returned to the faceplate of the lathe, and the flange *c* indicated to run true—the base must be attached to the faceplate so that both, if possible, or at least one of the screw holes in the base comes opposite a slot in the faceplate. The frame is then pushed on the base and the screws put in from the back, securely holding the frame to the base. In this position the inside taper bore of the frame is bored, and the end is threaded to fit cap *c*, Fig. 17—previously threaded—at the same setting, and the end of the frame is faced off.

After the hole is bored a splining tool is placed in the tool post and the spindle locked by means of the back gears, and a groove is splined lengthwise of the bore by sliding the carriage back and forth. Light chips must be taken until a groove about  $\frac{1}{16}$  inch deep is made. The spindle is rotated one-half or one-third and one or two more grooves are splined. These grooves are simply to prevent the babbitt from turning, and the accuracy of the spacing is immaterial.

The cap *c*, Fig. 17, is now screwed on the end of the frame, the edges smoothed by turning, and the hole bored to the desired diameter, which should be a sliding fit for the plunger *d*, Fig. 18. This completes the lathe work on the base, frame, and cap.

**Making Plunger.** The button *e*, Fig. 18, is next made on centers and the thread chased. Then the plunger *d* is made; being roughly turned on centers to say, within  $\frac{1}{16}$  inch of finish size. The long hole in the plunger is now drilled, bored, and threaded, by holding one end in the steady rest and the other end on the live center, a lacing in connection with a lathe dog being used to hold the plunger against the live center. When using a lacing, the faceplate should be loosened several threads, and, after the dog on the end of the plunger is securely tied to the faceplate, the plate is screwed against the shoulder of the spindle, which tightens the lacing and securely holds the plunger against the live center. After the hole is bored and threaded the button is screwed into the end of the plunger, and, placing the dog on the button, the plunger is turned perfectly straight and smooth and so it fits the hole in the cap. The end of the plunger is turned  $\frac{1}{8}$  inch smaller in diameter for a distance of 1 inch as in *d*, Fig. 17, and also in Fig. 18.

The lathe spindle is now locked and four unequally spaced grooves  $f$  are cut in the plunger the entire length but not deep enough to touch the reduced diameter at the end of the plunger. The grooves are to act as guides when babbitt is poured around the plunger, and the object of unequally spacing is to prevent returning the plunger in the babbitt bearing in any position but that in which the punch and the die line up.

The steady rest is now brought to bear on the reduced diameter, the recess  $g$  is bored for the punch holder  $h$ , and the shoulder  $i$  is turned to the desired diameter to act as a centrally locating member for the blanking die  $j$ . The diameter of the plunger is of course governed by the outside diameter of the blanking die which is attached to plunger, for it is obvious that a die larger than the plunger could not be withdrawn from the frame after the babbitt surrounds the plunger.

The points to be observed in making the plunger are: absolute straightness; grooves perfectly straight and free from chatter marks, and each one of a uniform depth its entire length; and the finished plunger absolutely free from blowholes caused by casting.

**Making Small Parts. Blanking Die.** It is immaterial in which order the remaining parts are made, as they will be only partly finished when turned to size in the lathe. The blanking die  $j$ , Fig. 17, should be made from the end of a bar gripped in a chuck and the large diameter of the die should be on the outer end, as in Fig. 19a, so that the recess can be fitted to the step on the plunger. The hole  $k$ , Fig. 17, should be bored at the same setting, and the diameter of the hole must be smooth and of the exact diameter desired at  $a$ , Fig. 15. The die is cut from the rod with a cutting-off tool in the lathe.

The piercing-punch holder  $h$ , Fig. 17, is also turned on the end of the rod, and the step  $L$  fitted to the recess in the end of the plunger. The upper stripper  $M$ , Fig. 17, should be turned on centers as at  $b$ , Fig. 19, and left on the piece of rod, for the next operation on the stripper is to mill to form the projections on the balance wheel, as shown at  $M$ , Fig. 17.

**Blanking Punch.** Instead of making the blanking punch  $a$ , Fig. 17, solid, then filing out the recess at each side of the crossbar, which would be a difficult job, the blanking punch is turned in the

manner shown in *a*, Fig. 19. The hole *N* is bored smooth to the exact diameter of *b*, Fig. 15, and the outside of the punch is turned to exactly the same diameter as *c*, Fig. 15. The large diameter of the

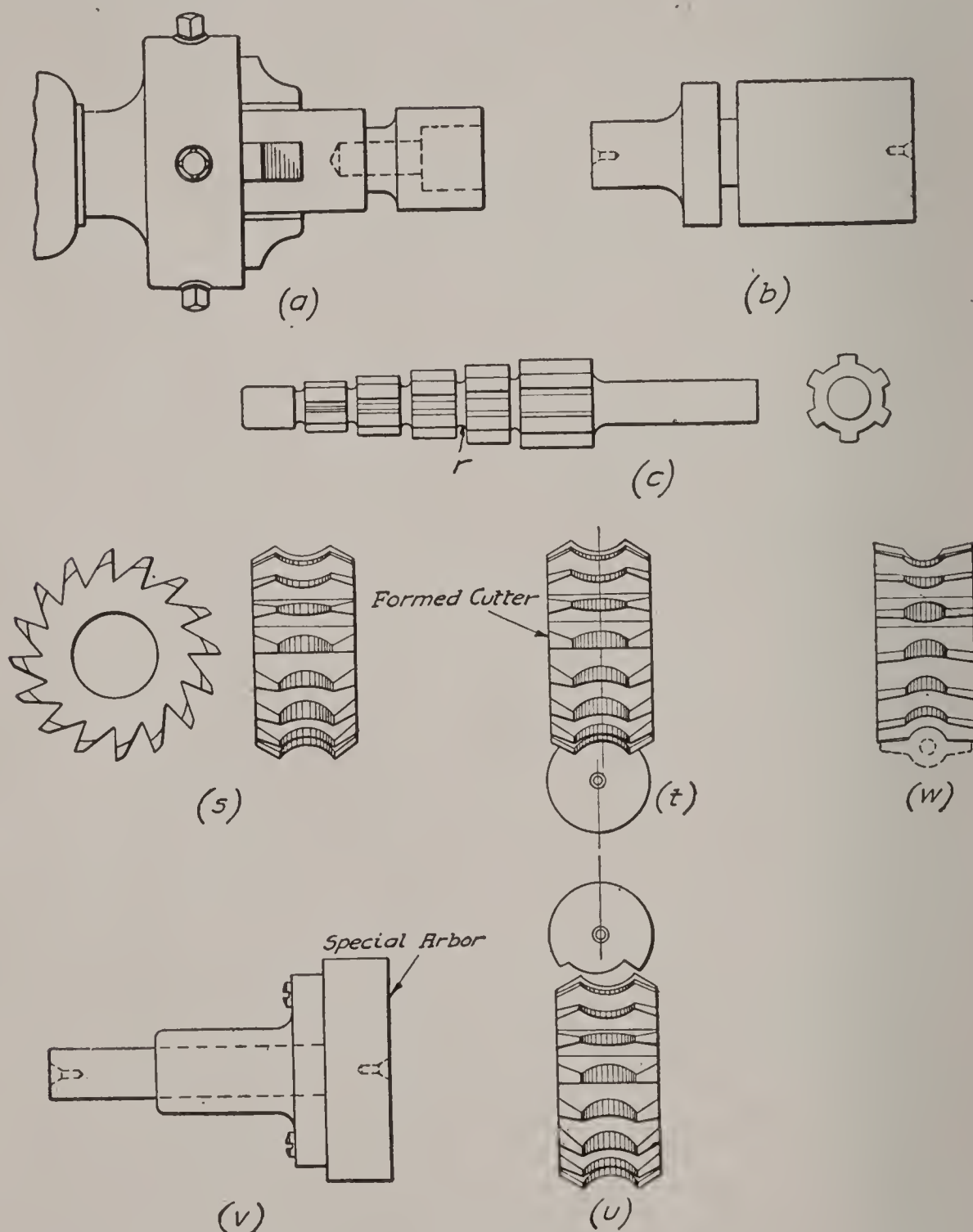


Fig. 19. Broaches and Cutters Used in Making Fig. 15

blanking punch is turned to fit the recess *a* in the base, Fig. 16, after which the punch is cut from the rod.

A die to produce the balance wheel cannot be readily ground to shape after hardening, therefore, an oil-hardening make of steel should be used, which will eliminate many chances of the die changing shape and will permit of machining the parts to exact size while soft.

The piece *o*, Fig. 17, which is milled to the shape of the cross-bar and when completed is inserted inside of the blanking punch, is turned on the end of the rod with the small diameter on the end of the rod. The diameter of the small end must be left  $\frac{1}{16}$  inch larger than the hole through the blanking punch, for the blanking punch is splined to a depth of  $\frac{1}{32}$  inch on each side, as in the enlarged section at *P*, Fig. 17, to position the ends of the cross-bar as shown in the assembled sketch *Q* of the end view of the blanking punch.

**Use of Special Cutters.** Before milling the spaces on the stripper and the blanking punch, it is necessary to make a number of broaches, *c*, Fig. 19. The number of broaches being governed by the depth of the projections or teeth. The broaches are turned on centers and the end pilot of each broach is made the same diameter on all broaches, and the pilot must be a good fit in the hole of the blanking die to be broached. The broaches are made in steps as shown, each step increasing in diameter by .005 inch. Chip clearance is provided at *r*. The broaches are numbered 1, 2, 3, etc., and the first step on broach No. 2 is made .005 inch larger in diameter than the last step on No. 1, and so on. The last step of the last broach has the same outside diameter as at *c*, Fig. 15.

A formed milling cutter *s*, Fig. 19, is now used to mill the spaces on the broaches, upper stripper, and the blanking punch. The milling cutter is set as nearly central with the center of the dividing head of the miller as possible. Then a test piece, which may be any scrap piece of steel or brass, is gripped in the chuck of the dividing head and milled as at *t*, Fig. 19. The dividing head is then rotated one-half of a complete turn, which brings the milled portion of the rod on the bottom side. Without disturbing the cross-movement of the table the milling machine knee is raised so that the milling cutter can be matched with the milled shape in the rod. If the formed cutter is not centrally located, it is readily noted, for when the milled rod is turned one-half revolution, the milled surface when matched with the cutter shows just double what the error is, as at *u*, Fig. 19, and by moving the table one-half the space shown between the milled form and the cutter and then milling a new place in the rod and repeating the operation of revolving the dividing head one-half revolution, the cutter can be very accurately set.

Having set the milling cutter central with the head or centers, the broaches are milled, and, without disturbing the setting of the milling cutter, the blanking punch is also milled, as is likewise the stripper *M*, Fig. 17. The blanking punch is held while milling on a special arbor having a shoulder as at *v*, Fig. 19, to grip the flanges of the punch and the stripper, as the small bearing surface in the straight hole in the blanking punch or the stripper would not be sufficient to prevent turning on an ordinary arbor when milling. The broaches are hardened, and then ground on the face by revolving them between centers and using a saucer or cup form of emery wheel.

The die *j*, Fig. 17, is now placed on a level surface in a power press which will permit the broach passing through the die. Entering the pilot of No. 1 broach in the hole in the die, the surface of the die is flooded with heavy oil and the broach is forced through the die. The succeeding broaches in their order are forced through in the same manner. The screw and dowel holes are put in the die, which completes it except for hardening.

The inside piece *o*, Fig. 17, of the blanking punch is milled with a formed cutter as at *w*, Fig. 19. At the same setting of the miller the crossbar for the inside of the stripper is milled, but this bar is made two or three thousandths thinner than the crossbar for the blanking punch. The blanking punch *a*, Fig. 17, is now clamped, face out, to the faceplate of the dividing head, a splining tool is secured to the arbor of the miller, the spindle of the miller is locked, and the two small recesses are splined the entire length of the straight portion of the hole in the punch. The recesses are to receive the ends of the crossbar punch *o*. Care must be exercised in setting the splining tool absolutely central with the center of the dividing head, and the blanking punch must be indicated by the hole so that it is central with the head of the miller.

**Fitting Piercing Punches and Dies.** It must be remembered that sub-press punch and dies do not enter when in use, therefore all parts can be made straight except the scrap punching dies. Clearance must be given to that part of the die where the scrap pieces or punches pass through, and when the pierced hole is irregular in shape, it of course is filed out. The piercing dies, however, as a rule are too small to permit the use of a die square, and for straight-

ness of side of filed openings or piercing dies the die-maker must depend upon skillful filing. In order to determine whether or not the piercing die has clearance on its entire length, babbitt is employed. The die is warmed slightly and laid face down on a piece of paper which in turn is on a flat surface, and the opening is filled with molten babbitt. When the babbitt is cool it should drop freely from the die if the die has proper clearance. When forced out, there will be polished streaks on the babbitt indicating just where the die has insufficient clearance.

As to fitting the punches of a sub-press die the same method is employed as in connection with the gang die shown in Fig. 37—that is, making and inserting the round piercing punches first and using them as guides, then as each irregularly shaped piercing punch is fitted it is left in the punch plate to act as an additional guide.

In making the piercing punches, they are attached to the punch holder and the holder plunger, the frame is assembled and babbitted, and the piercing punches are sheared while the plunger is guided by the babbitt bearing. The upper stripper, that works inside the blanking die, is blued on its face, and, removing the piercing punches from the plunger, the stripper is placed in the die, the plunger is replaced in the babbitt bearing, the stripper brought in contact with the blanking punch, and the outlines of the piercing dies are scribed on the face of the stripper. The stripper is then drilled out and filed to the lines. The punch plate containing the piercing punches may be tried from the back of the stripper, and the openings in the stripper filed until the piercing punches pass through to the face of the stripper without being forced.



Fig. 20.  
Prick-  
punch

**Placing Round Holes.** For transferring any round hole not centrally located from the templet to the punch holder or to the die, a small prickpunch, Fig. 20, is turned up, one for each hole, and the prickpunch must fit the hole. At the same time that the body of the prickpunch is turned to fit the hole the small point *b* is turned. The prickpunches are hardened, and the templet is clamped or held to the punch plate by a few small drops of solder, the prickpunch is entered in the corresponding hole in the templet and lightly tapped

on the end with a hammer. After the centers of all holes have been prickpunched the punch plate is strapped to the lathe faceplate, the prickpunch mark indicated, as shown in Fig. 21, and the holes carefully spotted and drilled.

The holes should be bored if possible. It is not safe to trust a drill starting centrally in a carefully made spot. Neither is it safe to trust a reamer to size a hole, even if the hole has been bored nearly to size, for a dull tooth on the reamer, or a soft tooth, or a hard spot in the steel at the edge of the hole, or a burr may cause the reamer

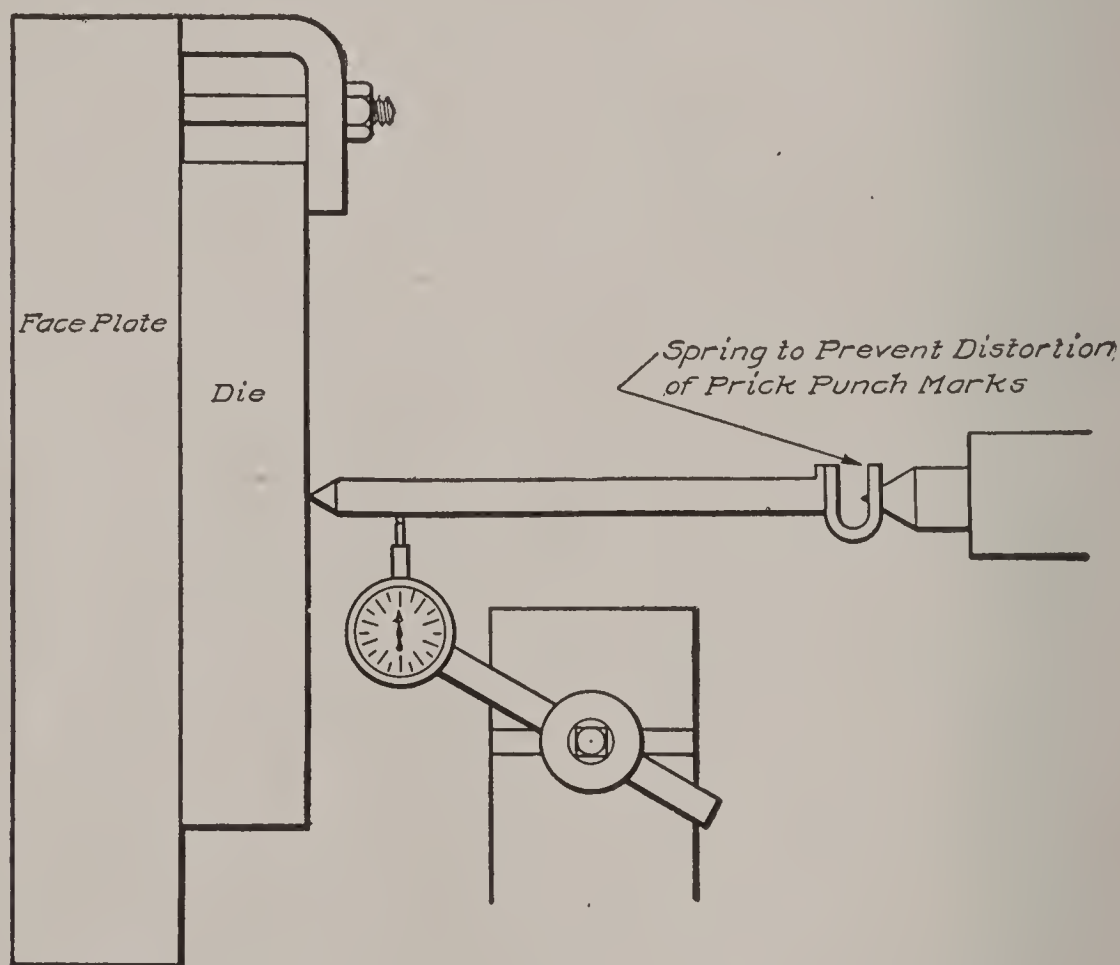


Fig. 21. Method of Locating and Indicating Prickpunch Mark

to deviate slightly. The only dependable method is to bore the hole with a single-pointed cutting tool—it does not matter whether the tool is stationary and the work revolves, or the tool revolves and the work is stationary.

*Use of Master Plate.* If the die being made is for a product that will be used year after year, or if the quantity of the product is such that new dies must be frequently made, it is good practice to make a master plate. This is done by machining a  $\frac{1}{2}$ -inch plate of soft steel or cast iron perfectly parallel, and of the same size as the die, then, when making the die, the plate is fastened to the face of the

die and the holes are put in as above described or by the button method through the master plate and die, the holes in the master plate being bored one size.

When making the next die the master plate is attached to the back of the die, a soft-steel center in the lathe is turned to fit the hole in the master plate, the master plate to which the die is attached is wrung on this soft center, and the die is clamped to the faceplate, and spotted, drilled, and bored. As the soft center in the lathe was turned, it therefore is central with the lathe spindle, and, as the center fits the hole in the master plate, it is obvious that a hole drilled and bored in the die will be directly in line with the hole in the master plate. This is the most accurate method of transferring holes. Great care must be exercised when transferring holes from a templet or a master plate to have the proper side of the plate against the die. For instance, in transferring from a templet to a die, one face is against the die, but, when using the same templet to transfer to the punch plate, the opposite face of the templet must be against the punch plate. This is caused by the face of the punch plate being up when transferring the holes, but down when the punch plate is in use.

**Assembling Parts.** The blanking punch and die, and the crossbar punch *o*, Fig. 17, for the blanking punch, are hardened, the bar punch is inserted in the blanking punch, and both punches are screwed to the base. The piercing punch *R*, Fig. 17, which is evenly coated on the face with solder is attached to the punch holder and the punch holder is attached to the end of the plunger. The blanking die is attached to the plunger by screws and dowels, but a thin parallel washer, or ring, a trifle smaller in diameter than the outside diameter of the die and about  $\frac{1}{32}$  inch thick is placed between the blanking die and the plunger to cause blanking die *j* to protrude  $\frac{1}{32}$  inch beyond the face of punch *R* so that blanking punch *a* can be entered in the blanking die. The frame is now fastened to base, care being exercised that there is no grit between the bottom of the frame and the top of the base.

The plunger is placed inside the frame, and the punch and die entered. The frame cap *c*, Fig. 17, which fits the plunger is screwed on the end of the frame, which locates the plunger centrally in the frame. The entire mass is now inverted, and, resting the cap on

parallels the frame is slightly heated with a gas torch, and the molten babbitt is poured in the frame. Putty is used at the die end of the plunger to prevent the babbitt leaking. The whole mass is allowed to become thoroughly cooled before disturbing. When cool, the inside outline of the blanking punch is forced into the soft solder on the face of the piercing punch.

The plunger is now removed from the frame, piercing punch *R*, Fig. 17, is removed from the plunger, and slot *S* is milled or shaped to the line on the solder. After milling very close to the line the parts are reassembled and the punch is sheared far enough to obtain a good impression on the steel punch. The punch is now carefully milled or filed to remove all marks of shearing.

### SECTIONAL DIES

**Advantages.** When dies are large or when there are many weak projections, it is good practice to make the dies in sections.

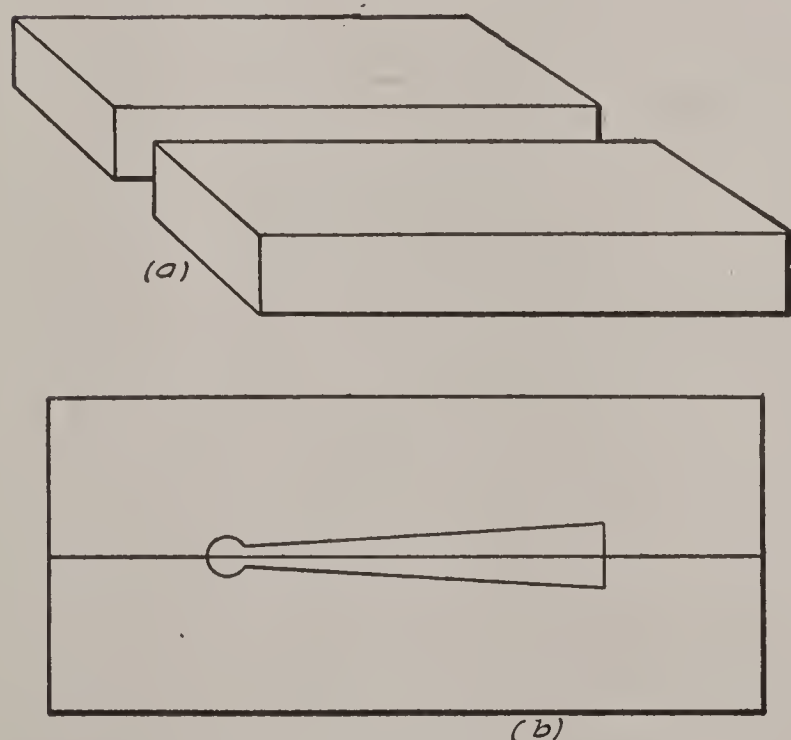


Fig. 22. Clamping Sectional Die for Outlining

One reason is that the individual pieces of a large die can be machined to shape easier. Another reason is that a long die or a large die would distort appreciably when being hardened, which would mean that the die could not be finished to exact size, but that a considerable amount of stock must be left on the large solid die in order to grind to shape after

hardening. In the case of weak projections in a die, if the die is left solid and one point breaks, the entire die is ruined, whereas, with a sectional die, that part containing only the broken portion can be removed and a new one made at a small cost.

**Laying Out Die.** The procedure in making such a sectional die as in Fig. 325, Tool-Making, Part III, would be to machine the two strips as in Fig. 22, herewith, and, clamping them together, to lay

out the outline from a templet or drawing in the same manner as the die in Fig. 4 was laid out.

**Shaping of Die.** The parting line of the two halves should come in the center of the scribed outline. The operation of drilling along the line as in the case of the die in Fig. 4, would be useless,

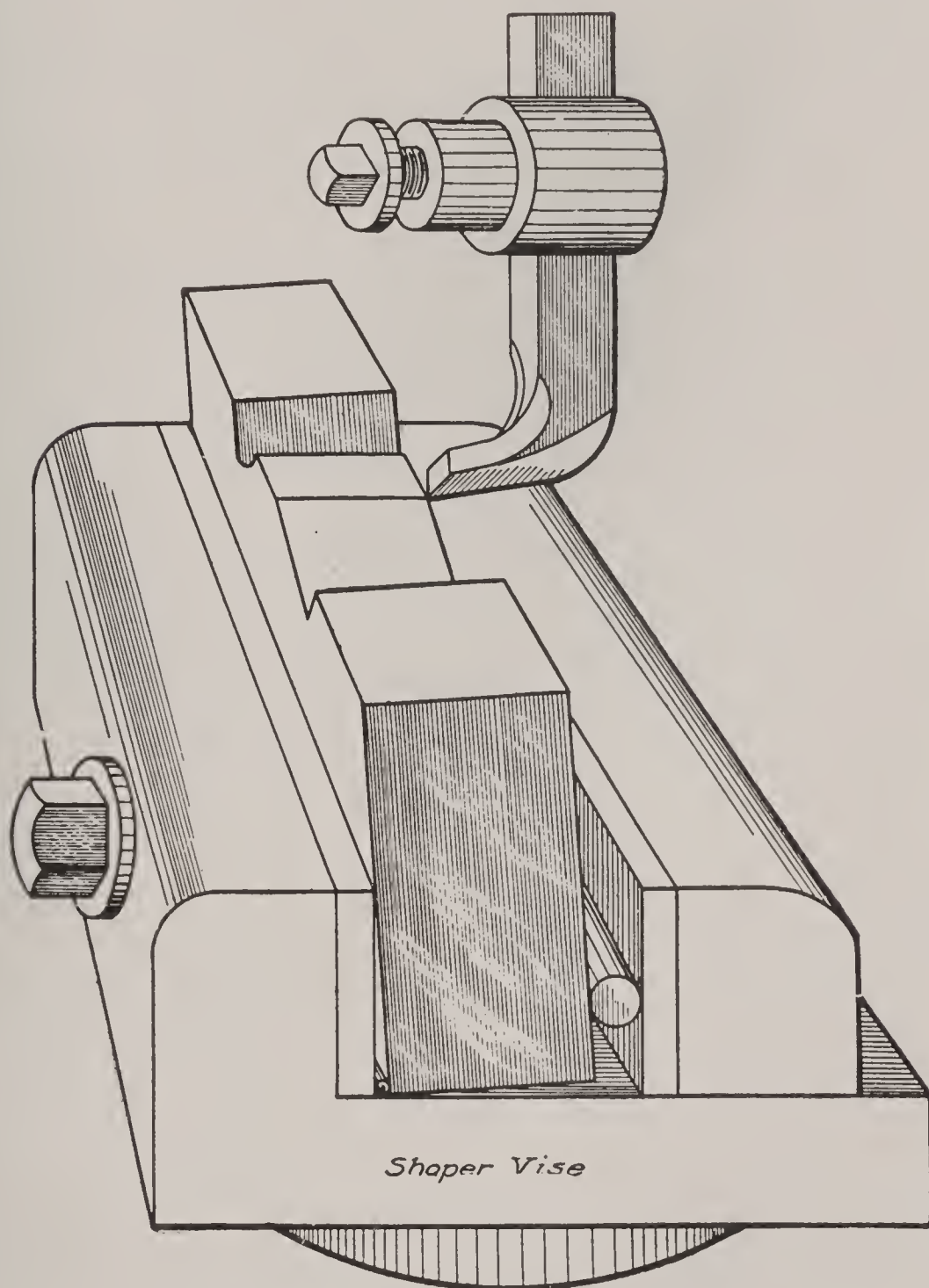


Fig. 23. Shaping Die, Showing Method of Obtaining Clearance

for the end hole can be drilled, and reamed tapering, then each half in turn may be gripped in a shaper vise, Fig. 23, and, by placing a small wire or a strip of folded paper of the right thickness to tilt the strip at the desired angle for clearance, then placing, say, a  $\frac{1}{2}$ -inch rod at the mid height of the jaws, the opening in the strip

can be easily machined to size and the clearance can be machined at the same time.

*Shearing Precautions.* Several dowel holes are drilled in each strip, if possible, in addition to the screw holes for fastening to the die shoe, and, after hardening and grinding the die strips, the die shoe is machined to receive the two strips. A snug fit is necessary. The dowel holes are now transferred from the die strips to the die shoe, and the dowels are inserted. There is always more or less spring to a sectional die when shearing the punch. Care must be exercised in not attempting to shear too much stock, as the dies will spread.

Fig. 24 shows the method employed in making a small sectional die of simple design having weak projections. It is obvious that weak points, such as shown on this die, would not withstand the

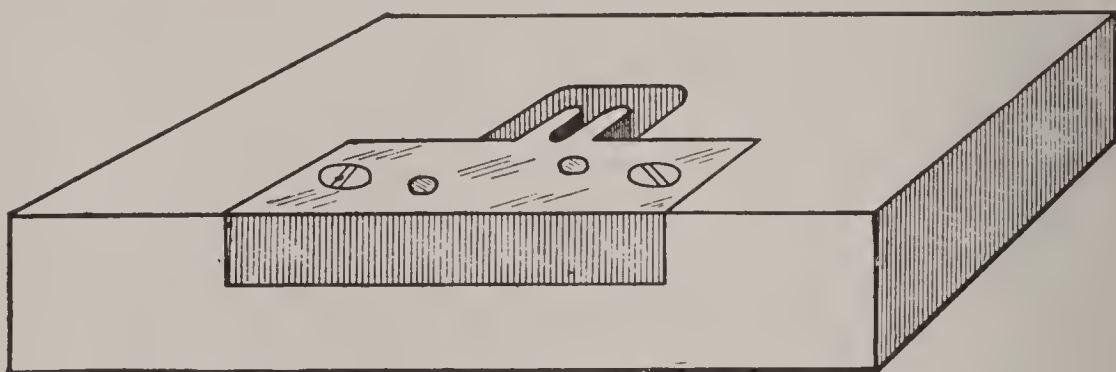


Fig. 24. Making Sectional Die with Weak Projections

pressure necessary to shear much stock. Therefore, when shearing a punch having such points, always remove the stock by scraping or filing and do not allow the points in the die to shear the punch. Great care also is necessary in withdrawing a punch from a die of this character when shearing the punch.

#### Hardened and Ground Sectional Type

**Construction Requirements.** The cores for coils and armatures are made up of variously shaped laminated soft-iron punchings, which, as a rule, must be extremely accurate. The iron sheets are rolled hot, producing a hard scale or oxide which causes severe wear on punches and dies. The dies must be frequently ground, as burrs on punchings are prohibited, and if the dies were given clearance each grinding would produce a larger punching. Therefore, due to intricate shapes that must be exact and the fact that the wear on

the dies is severe, the dies are invariably made of the sub-press construction and also made up of pieces, the latter being ground all over to size after hardening. There is no clearance given these dies and they are known as sectional or built-up dies.

*Intricate Shapes.* When the die is of extremely intricate shape, having a great number of pierced slots, Fig. 25, the usual method is to make a single punch and die, and, by the use of an accurate indexing fixture which holds the blank, the notches are pierced one at a time and the indexing done automatically by the stroke of the press. One operator can attend to several presses. The object in indexing and using a single piercing die is to eliminate the high cost of making a die to produce the blank in one stroke and also to eliminate the cost of repairs, for if one small point on such a die should break it would render the entire die useless until repaired.

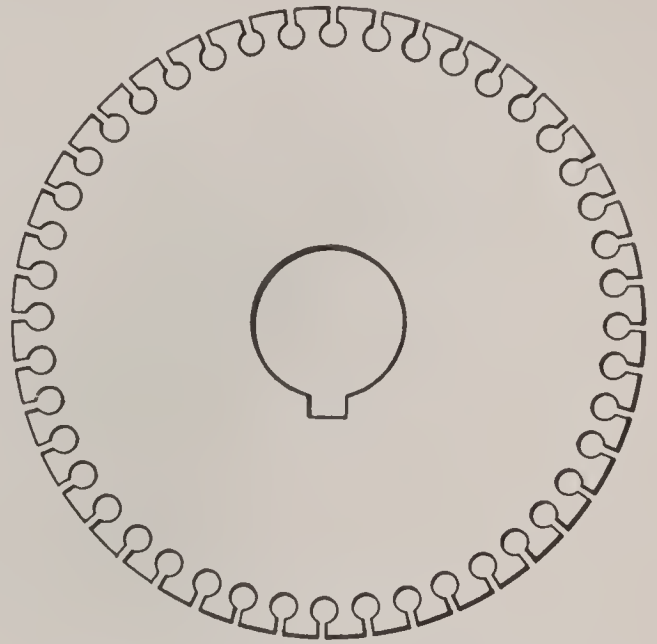


Fig. 25. Die with Pierced Slots

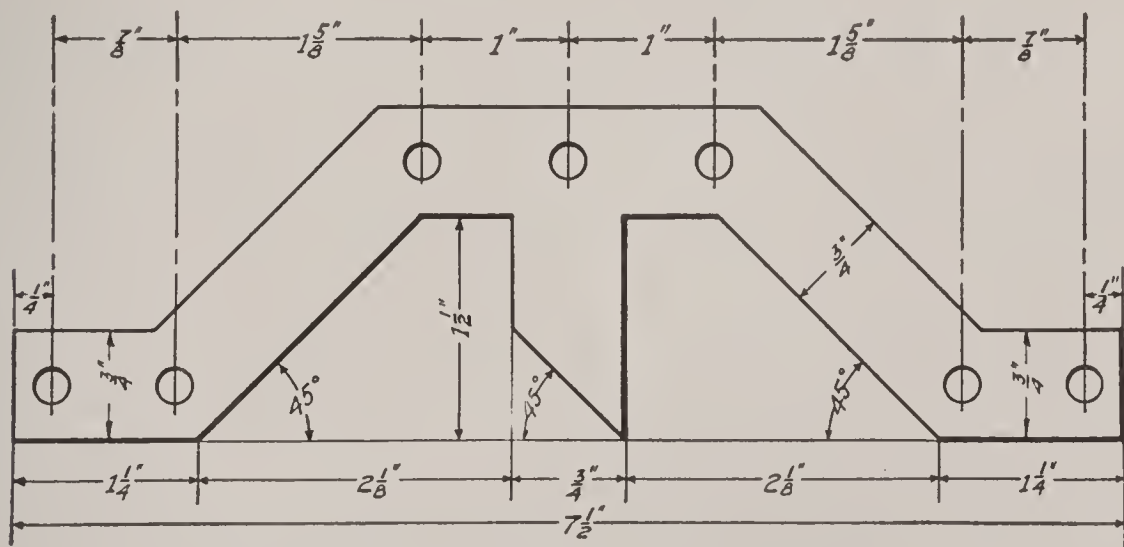


Fig. 26. Typical Punching with Dimensions

The punching shown in Fig. 26, while extremely accurate, is of a comparatively simple design, but the method of making is the same as for dies for more intricate shapes. The punchings are built up as in Fig. 27, and every other one is reversed, so that the error must be slight, for in reversing the blanks the error is doubled.

**Making of Die.** *Division in Pieces.* When laying out a built-up die that is to be ground to shape and size after hardening, the

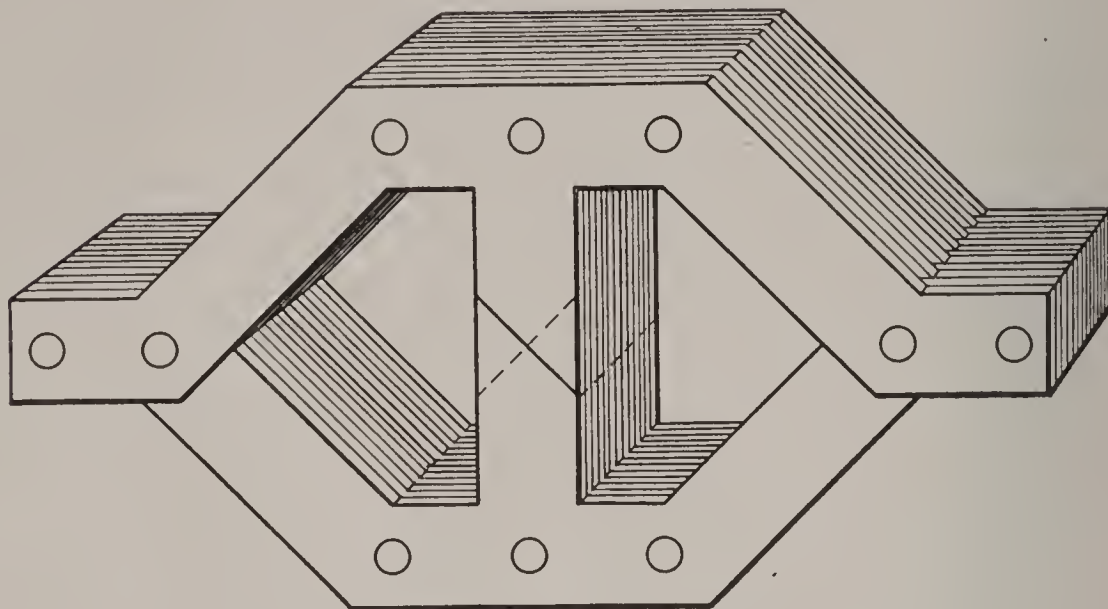


Fig. 27. Method of Mounting Punchings Shown in Fig. 26

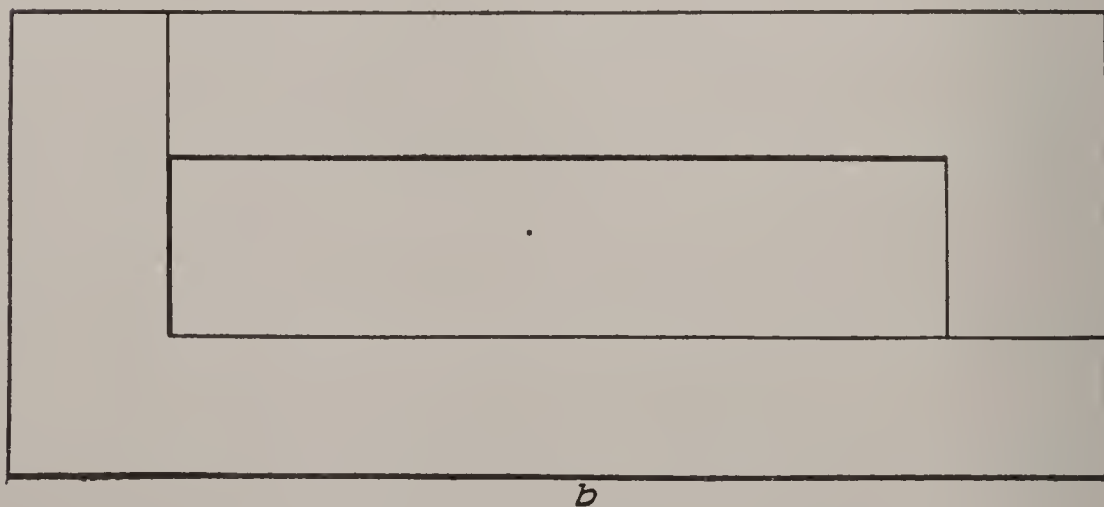
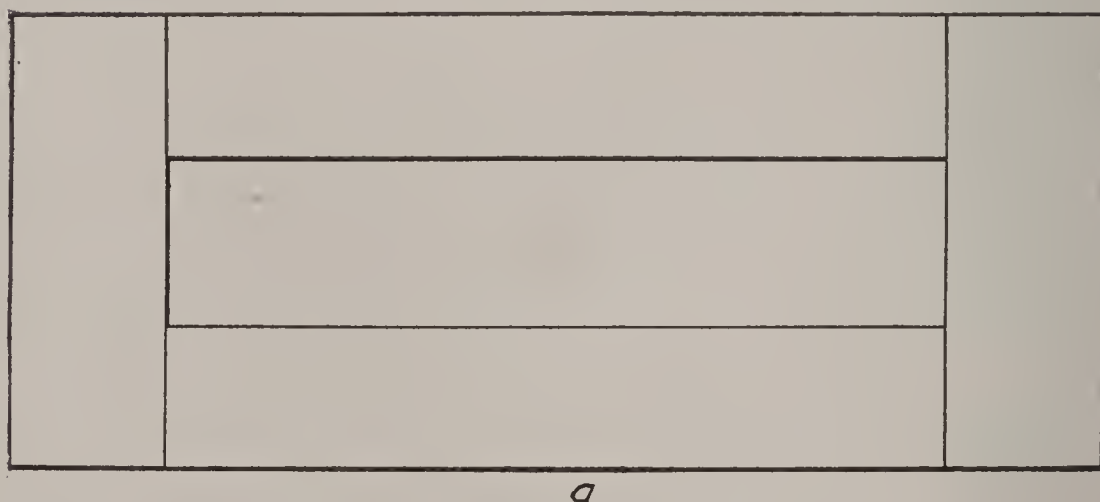


Fig. 28. Two Methods of Making Sectional Die

sections should be as free from internal corners as possible, as it is a difficult job to grind a good sharp inside corner. For instance, referring to Fig. 28, it would be easier to make and grind the four

pieces, as at *a*, than it would be the two pieces with inside corners, as at *b*. Therefore, the division of the die at hand for sections requires considerable study.

Referring to Fig. 29, it will be seen that the division lines are so placed that there are no corners in any one piece and that each piece is comparatively easy to make. Instead of laying out from a templet, or roughing out the pieces and placing them in position, then laying out the outline on the pieces, a better way is to make

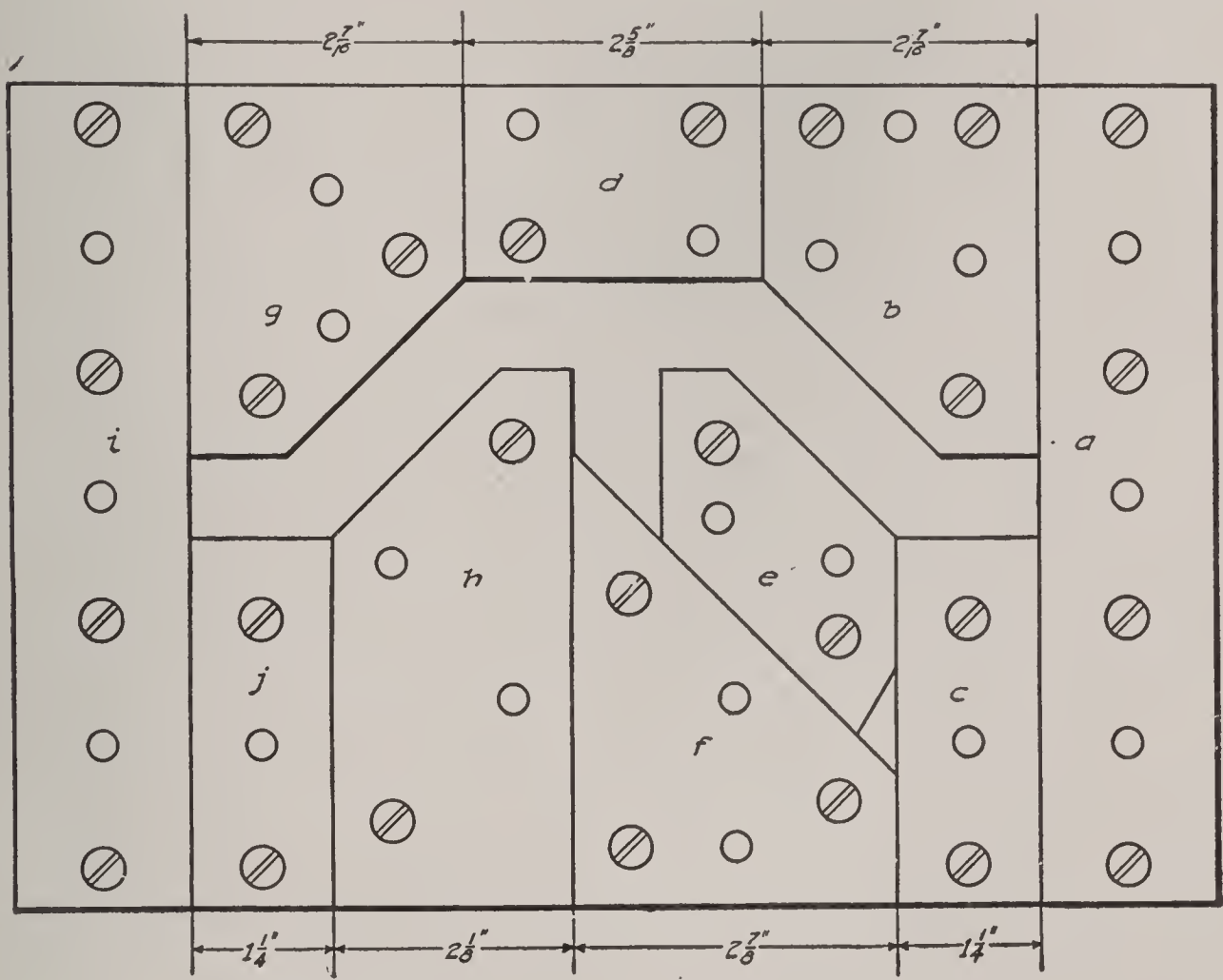


Fig. 29. Building Up Die for Punching Shown in Fig. 26

each piece by measurement. The pieces *a* and *i* are simple end pieces, perfectly straight, and can be eliminated from the description of making. Referring to piece *b*, Fig. 29, we find by totaling the dimensions on the drawing, Fig. 26, that the piece is  $2 \frac{7}{16}$  inches wide and that the angle is 45 degrees. This piece is carefully planed or milled to exact shape, but, say, .010 inch is left on each surface for grinding. Piece *c*, Fig. 29, is important, as the width governs the length of the end of the punching. Referring to the drawing, Fig. 26, we find this width to be  $1 \frac{1}{4}$  inches, and .010 inch is left on each surface for grinding; and so on, until all pieces are

roughed out to within grinding allowance. The edges and bottom of all pieces must be at right angles even when in rough size.

*Doweling Hardened Pieces.* After all pieces are roughed out the screw and dowel holes are drilled. The dowel holes, however, are drilled, and then tapped with a fine-pitch thread; if a  $\frac{3}{8}$ -inch dowel is used, the holes can be tapped, say,  $\frac{1}{2}$ —32 pitch. The object of tapping the dowel holes is to permit screwing in tight-fitting soft-steel plugs after the pieces have been hardened, following which the plugs are dressed off flush with the top and bottom of the piece. Then after all pieces are ground to size and securely fastened in proper place by means of the screws, the dowel holes are drilled and reamed through the soft-steel bushings or plugs and into the die shoe. This is better practice than to drill and ream the dowel holes in the pieces before hardening, for, after hardening the pieces, the holes are slightly distorted; but, granting that the holes remained true, it becomes necessary to transfer the holes to the die shoe, and in order to do this a drill is used, using the dowel holes in the hardened pieces as a jig. The drill used must of necessity be somewhat smaller than the hole in the hardened piece, possibly not more than one or two thousandths, but whatever the difference between the drill and the hole is, that difference can cause an error in the alignment of holes in the hardened piece and in the die shoe, as the drill can bear against one side of the guide hole, drilling the hole off center. Using the hardened pieces for a guide prohibits the use of a reamer, for, in order to have the reamer size the hole in the die shoe and to bring the hole in the die shoe absolutely in line with the hole in the piece, the reamer must fit the hole in the hardened piece, which of course would ruin the reamer. The greatest objection to using the holes in the hardened piece for a guide for the drill and reamer is that the holes are invariably distorted during the hardening process.

Having drilled and deeply counterbored all screw holes, and drilled and tapped all dowel holes, the pieces are hardened, but, as the die is to cut iron having scale, the die is left harder than for ordinary sheet steel.

*Grinding Pieces.* The first grinding operation is to take a chip across a temporary bed, or the grinder bed itself, or the face of a magnetic chuck to insure the surface being parallel with the travel

of the cross-slide and the travel of the bed. The pieces are examined on the bottom side to make sure no burrs are protruding or scale adhering to the pieces that would tilt them, for there is only an allowance of .010 inch to remove, and a slight tilt might be sufficient to prevent the pieces cleaning up all over. All pieces are then placed on the newly finished bed and waxed to the bed, unless a magnetic chuck is employed. After all pieces are ground on the top side, the wax is thoroughly removed from the bed, the pieces cleaned, and the surfaces just ground are waxed to the bed, and the bottoms then ground. All pieces now are of uniform thickness and parallel.

An angle iron, or, what is better suited for this class of work, a hollow square, absolutely square in every position, Fig. 30, is now

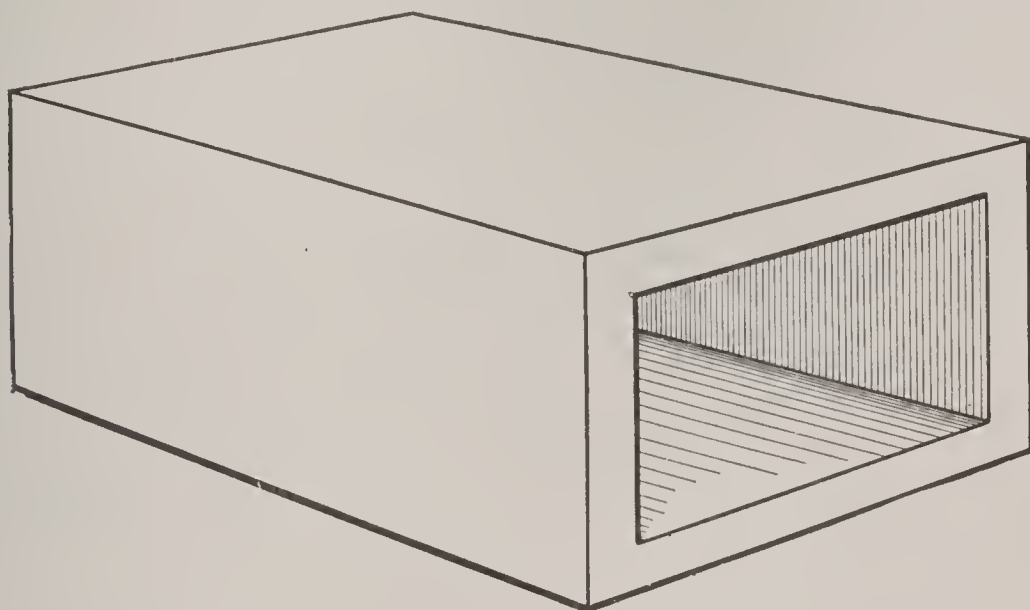


Fig. 30. Hollow Square Used for Holding Pieces for Grinding

waxed to the surface of the newly machined bed. In either case the angle or hollow square must be absolutely square and must be waxed to the bed so that the vertical face of the angle is absolutely parallel to the line of travel of the bed. This is accomplished by clamping an indicator to the side of the wheel. Do not trust a square against the machined surface of the uprights of any machine, if the surface of the work must be parallel with the line of bed travel, for by so doing we are trusting to the accuracy employed by the machinist who built the machine: eliminate all chance.

Assuming that the hollow square is correctly located and waxed to the bed, the first piece to be ground can be *a*, Fig. 29. By clamping the piece to the hollow square and using the indicator attached to a surface gage, the piece can be positioned parallel with the surface

of the bed by testing each end of the piece for height, using the indicator. The piece need project above the hollow square only a slight distance, say  $\frac{1}{16}$  inch. As the top and bottom of piece *a* are perfectly parallel and the hollow square is perfectly square—at right angles—it is obvious that when the upper face of piece *a* is ground, the face will be at right angles with the top or bottom.

Piece *b*, Fig. 29, is clamped to the hollow square, as in Fig. 31, and the end of the piece is lined up with the bed by placing a square on the bed. The use of a square will be found accurate enough for the grinding of the first edge, but, after one edge is ground, if the remaining edges are trued up at right angles with each other by holding the base of a square against the vertical edge of the work, and using an indicator clamped to the emery wheel and with pointer

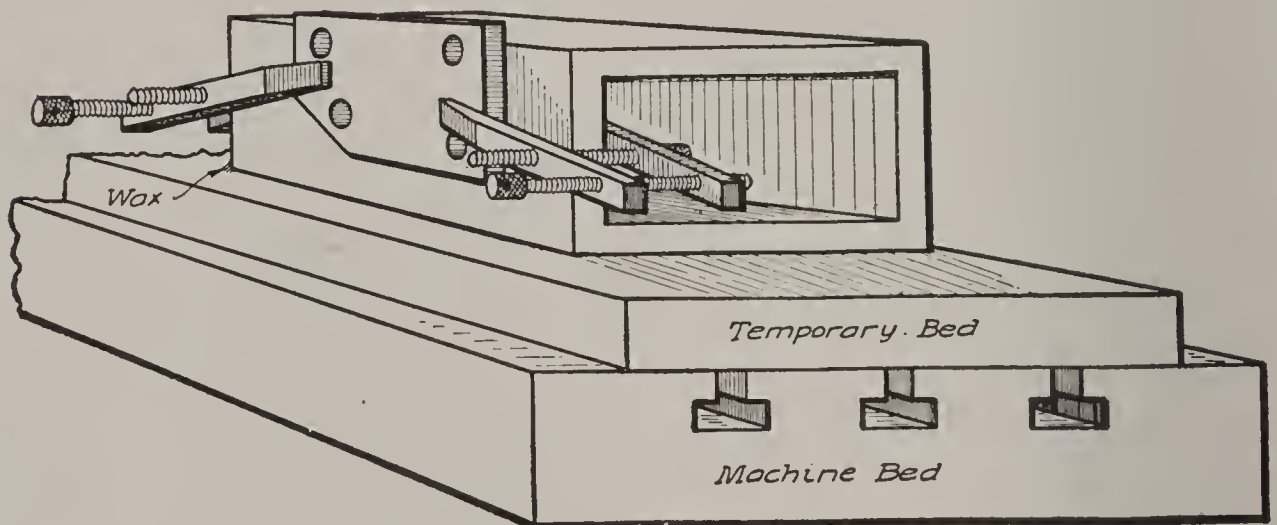


Fig. 31. Piece Clamped to Hollow Square on Machine Bed

sliding along the blade of the square, as in Fig. 32, the work can be made more accurate than by holding the blade against the work while the base of the square is on the bed of the machine. After the first edge has been ground, the piece should be tested, as in Fig. 33, to prove that the side of the hollow square is at right angles with the bed, as grit can get under the hollow square unless extreme care is exercised. The piece *b* now being ground on two sides, its succeeding sides or edges may be ground by a similar procedure.

Each piece must be ground on the edges as above described, always using the indicator to square up the work, for the use of parallels is not safe. A slight nick on a parallel or a piece of grit or even a slight taper of the parallels would of course be transferred to the work.

*Placing Die Pieces on Shoe.* After all pieces have been ground to exact dimensions, they are attached to the die shoe and placed in position by soft test pieces that have been machined the right thickness. These test pieces are placed in the opening of the die, and the die pieces are brought to bear against the test piece, in which position the hardened pieces are securely fastened in place by

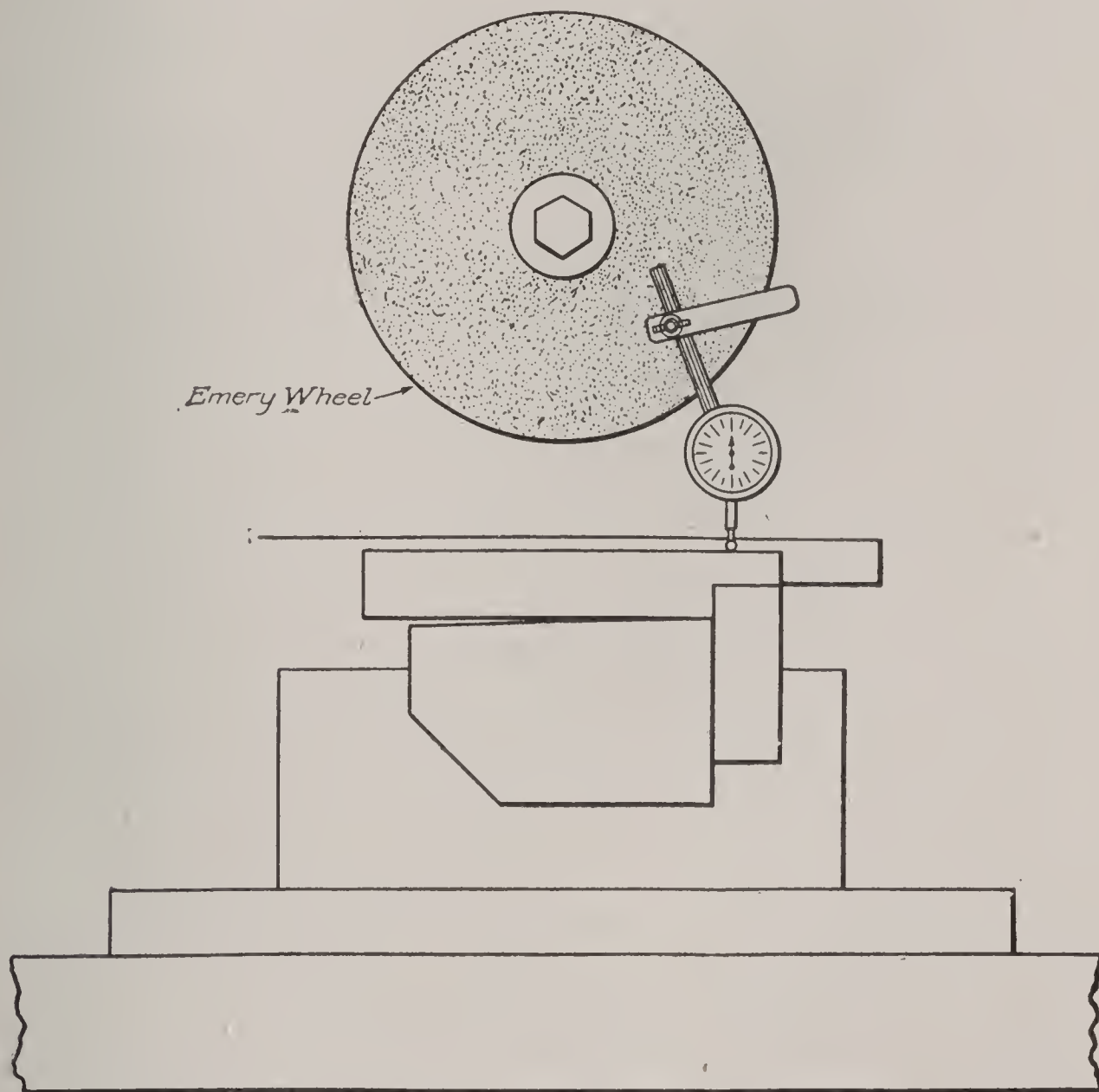


Fig. 32. Emery Wheel and Indicator Mounted for Grinding

screws. After tightening the screws the die should be gone over again to see if some piece had moved a trifle when tightening the screws; then drill and ream for dowels.

**Attaching Piercing Punches.** While the die pieces are attached to the die shoe, the die shoe is in turn attached to the punch holder, as the die in all sub-press construction where piercing punches are employed in conjunction with blanking operates as the upper member. It will be noted that the piercing punches for the holes shown

in Fig. 26 have not been inserted in the die as yet, for the reason that it is easier to put the piercing punches in place after the die is complete. This is accomplished by drilling holes in the die shoe approximately where the punches will come but by making the holes a trifle larger than the larger diameter of the punch and then inserting the piercing punches in small individual punch holders, these punch holders in turn being attached to the back of the die shoe, the punches can be properly located from the holes in the blanking punch by shifting the individual holders one way or another and may be securely screwed to the die shoe when the punches are in proper location. The individual punch holders can be inserted in recesses

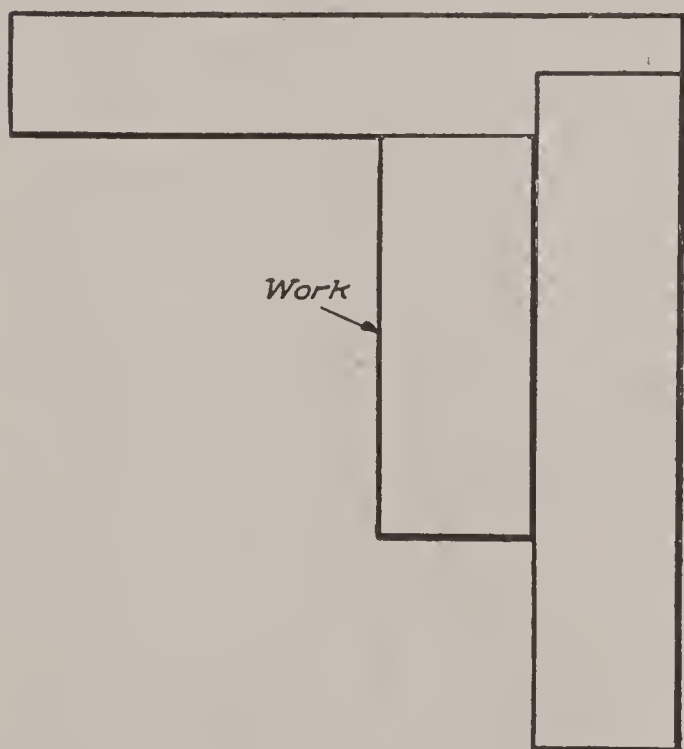


Fig. 33. Proving Accuracy of Work after First Edge Is Ground

in the die shoe, or can be screwed on top of the die shoe, and the punch holder recessed to clear them. The locating of punches in this manner eliminates considerable boring of a very accurate nature. Another method of inserting the piercing punches in the upper half is to complete the blanking punch, then the die, and, by entering the punch in the die, the holes in the blanking punch which are the piercing dies can be transferred to the die shoe. This

is not as accurate, however, as the adjustable punch-holder method.

**Making Blanking Punch.** The blanking punch is also made up of pieces and is more difficult to make than the die, for the holes in the blanking punch which are the piercing dies must be very accurately located and bored, and, after hardening the punch pieces, the punch pieces are ground to shape and dimensions from the holes.

*Measuring from Piercing Holes.* The holes are put in the soft pieces of the punch after the pieces have been roughed out to within the grinding allowance. After hardening, the holes are thoroughly cleaned, and taper plugs are turned of soft steel to fit the tapered holes. That portion of the plugs, however, that extends beyond

the face of the punch, Fig. 34, is straight and all diameters must be exactly alike. When grinding the punch sections, the plugs rest on the hollow square or on the top of the angle iron to insure the edge being ground parallel with the hole, and the method of measuring for proper thickness is as shown in Fig. 34. The small projecting plugs must be of exactly the same diameter, but the actual diameter is immaterial. The punch thickness is  $\frac{3}{4}$  inch, and, assuming that the projecting ends of the plugs in the holes are .250 inch in

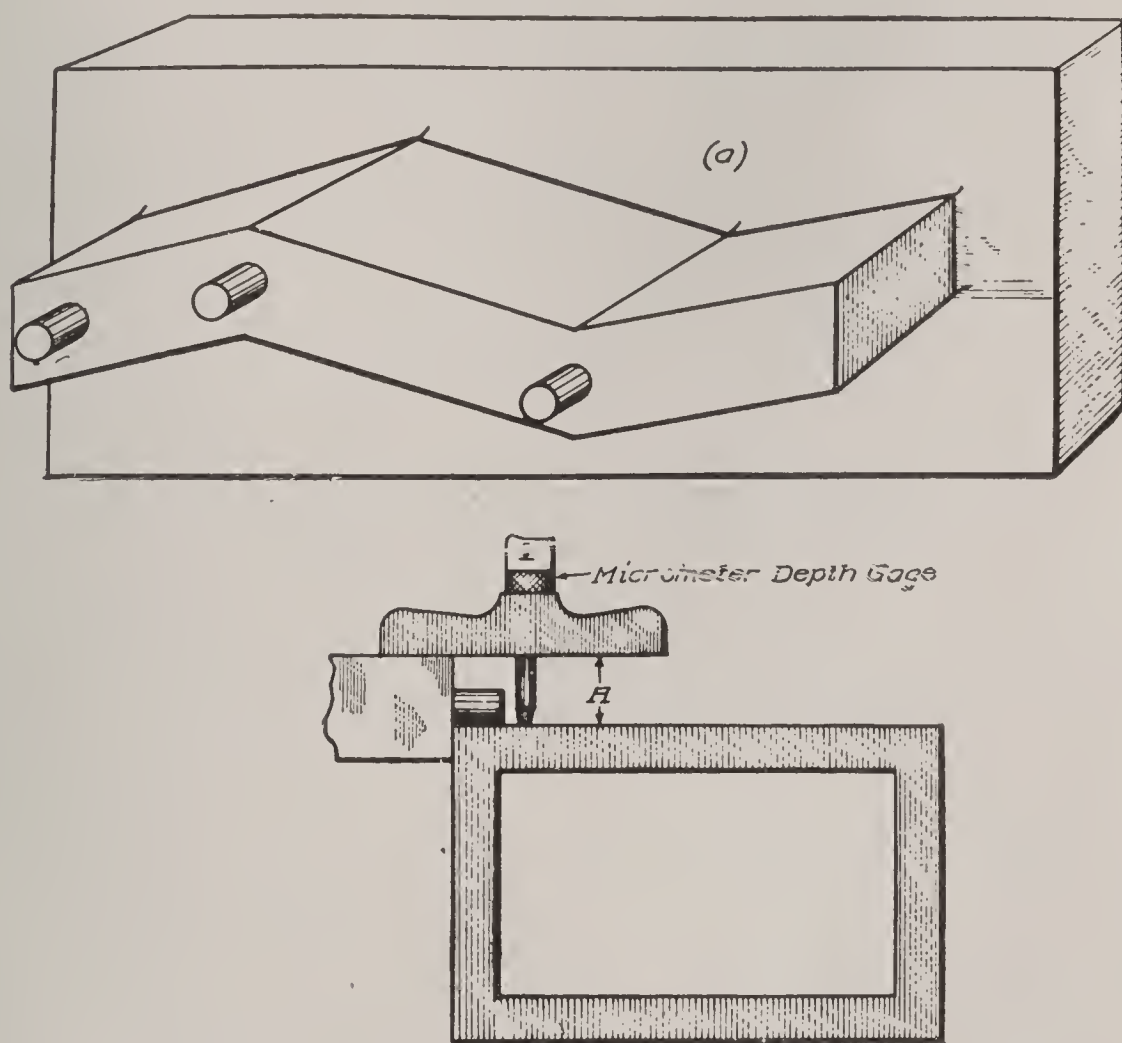


Fig. 34. Measuring Thickness of Piece with Depth Gage

diameter, it means in this instance that the distance  $A$  must be one-half the thickness of the punch plus one-half the diameter of a plug or  $.375 + .125 = .500$  inch.

*Discrepancies.* When a portion of a punch is at an angle, the grinding of the punch sections requires considerable care and skill due to the fact that discrepancies on abutting ends of punch sections will greatly multiply themselves at the extreme ends of the punch as in Fig. 35. A slight opening as at  $a$ , Fig. 35, is permissible.

The object in making the punch thin, then attaching it by screws to the soft-steel punch block  $a$ , Fig. 34, is for rigidity. It

would be easier to make the punch as in Fig. 36, leaving enough stock to grind to size, then grinding out the holes to proper location, but the face of the punch that bears against the holder is too narrow

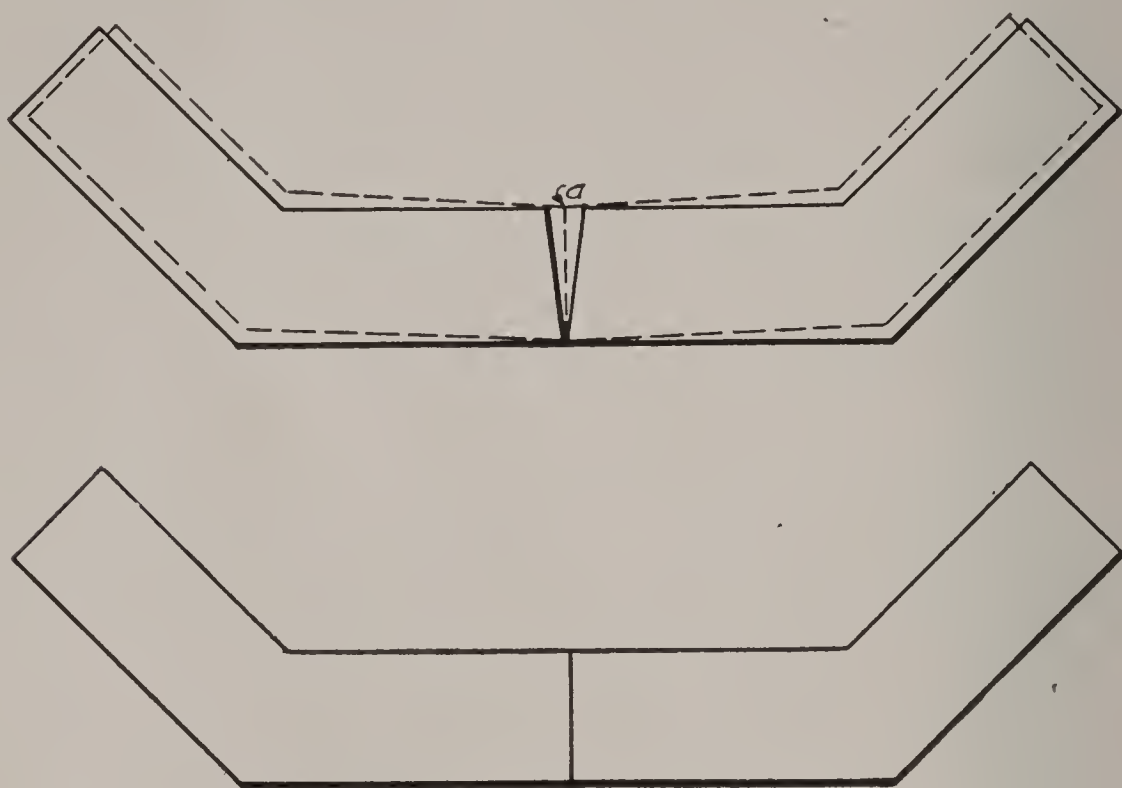


Fig. 35. Sectional Blanking Punch, Showing Exaggerated Opening for Making Adjustments and Completed Sections

for a working seat, and any miscut by the press operator, or a piece of scrap punching adhering to the sheet being punched, would

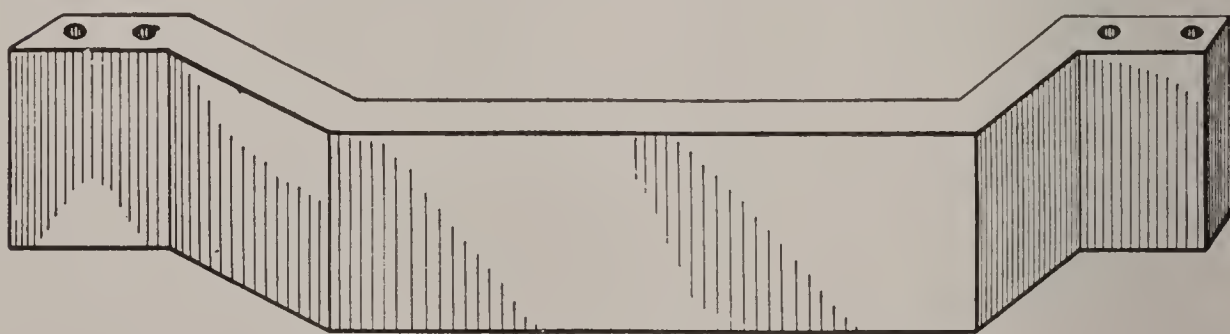


Fig. 36. Punch Easier to Build than Fig. 35 but Not So Satisfactory

cause the punch to spring to one side. This causes the edge of the punch to strike the edge of the die, and a broken member or a sheared punch is the result.

### GANG DIES

**Accuracy Required in Making.** By referring to Fig. 341, Tool-Making, Part III, it will be noted that in addition to the blanking punch there are two piercing punches attached to the same holder. Since these piercing punches, as well as the blanking punch, must

be in perfect alignment with the dies, the method of procedure is different from that in connection with the simpler dies, and a gang die requires careful laying out. Assuming that the die we are about to make is the shape and type shown in the illustration referred to, we will first consider the different methods which could be employed to make the die, and then select the most practical one.

*Drilling and Filing Method Precluded.* A true radius is shown at each end of the blanking die *E*. If we were to drill holes just inside the lines and to broach out the center piece as described for the die of Fig. 4, difficulty would be experienced in filing the ends, as it is extremely difficult to file a true radius. Besides, this method would entail considerable hand work, and it is good practice to eliminate hand work as far as possible. The drawing, Fig. 37, calls for a positive distance between the two piercing dies, and also calls for a blank 2.250 inches long. It is shop practice that, when dimensions are given in thousandths of an inch, the dimension is important and must be adhered to within a thousandth. When given in four decimals, finer accuracy is required, but when given in fractions, a variation of several thousandths is permissible. Therefore, the length of the blank being important, and the ends of the blank being of a true radius, the drilling and filing method is precluded.

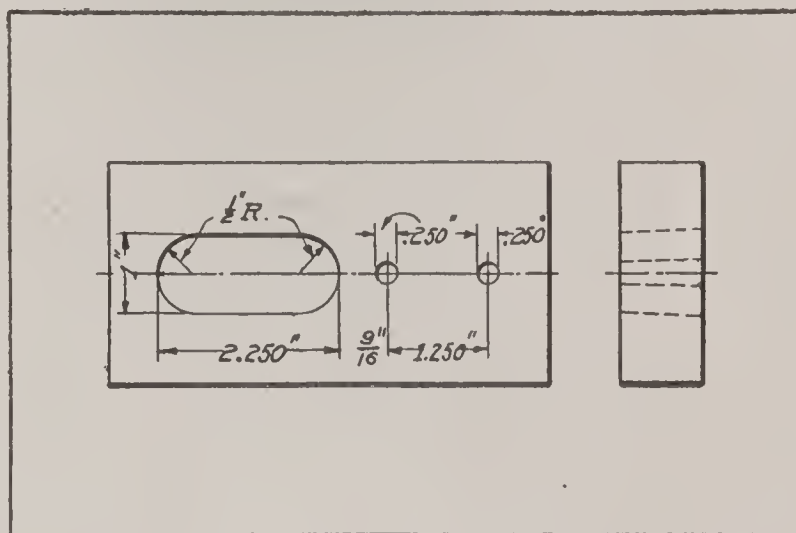


Fig. 37. Drawing for Gang Die Blank

*Errors of Drilling and Counterboring Method.* The location of the holes and blanking die could be laid out with a height gage, and, where the lines cross, fine prickpunch marks should be placed, from which as starting points the holes could be drilled and counterbored to proper depth for bushings or counterbored clear through for the piercing die proper. But there are several chances for errors in this method: (1) The prickpunch mark may not be placed exactly at the intersection of the lines. (2) The drill may not have started exactly in the center of the prickpunch mark, or granting that it

did, the drill can *run*, which is the shop term applied to a drill leaving its intended travel or path. (3) The holes must be given clearance, and, since they are drilled, the taper reamer is the logical method. We have already shown how a taper reamer will start on an angle carrying the center distance of holes one way or another. (4) When drilling and counterboring the two end holes to form the radial ends of the blanking punch, the prickpunch can be out, the drill can start wrong, and the pilot of the counterbore in not fitting the hole can change the center distance and the counterbore may cut too large even though it measures the proper diameter. (5) The final opportunity for error is in the reaming of holes for clearance. All these chances for errors must be considered, and here again is where a careful study of the drawing would show that the ordinary easy method cannot be used.

**Approved Method of Making.** The proper sequence of operations to make this particular die would start with planing up the die block, stripper, and punch plate.

*Placing Holes.* If the piercing punches *BB* in Fig. 341, Tool-Making, Part III, were, say, 1 inch in diameter, it is obvious that the punch holes in the punch plate and the die holes in the die must be exactly in line, as a large punch will not spring into the die as is the case with punches of small diameter. Therefore, the best way to make these holes in line would be to dowel the stripper to the die face and dowel the punch plate to the stripper, then lay out the holes by means of a height gage, and indicate the center mark on the punch plate true by clamping the die block containing the stripper and the punch plate to the faceplate of a lathe. Then spot the punch plate with a V-spotting tool held in the tool post, and drill, and bore the punch plate and stripper to the desired diameters. Remove the punch plate and stripper and bore the larger recess in the die for bushing. The die must be clamped to the faceplate in such a manner that the punch plate and stripper can be removed without disturbing the location of the die on the faceplate. Very accurate results can be obtained in this manner, providing the holes are bored after drilling.

A more accurate method of locating the holes is to attach the punch plate and stripper to the die, then lay out approximately the location of the holes on the rear side of the punch plate. A small

hole is drilled and tapped say for a No. 10—32 screw in the center of the approximate location for the holes. Buttons that are faced on one end at right angles with their sides and that have a hole, say,

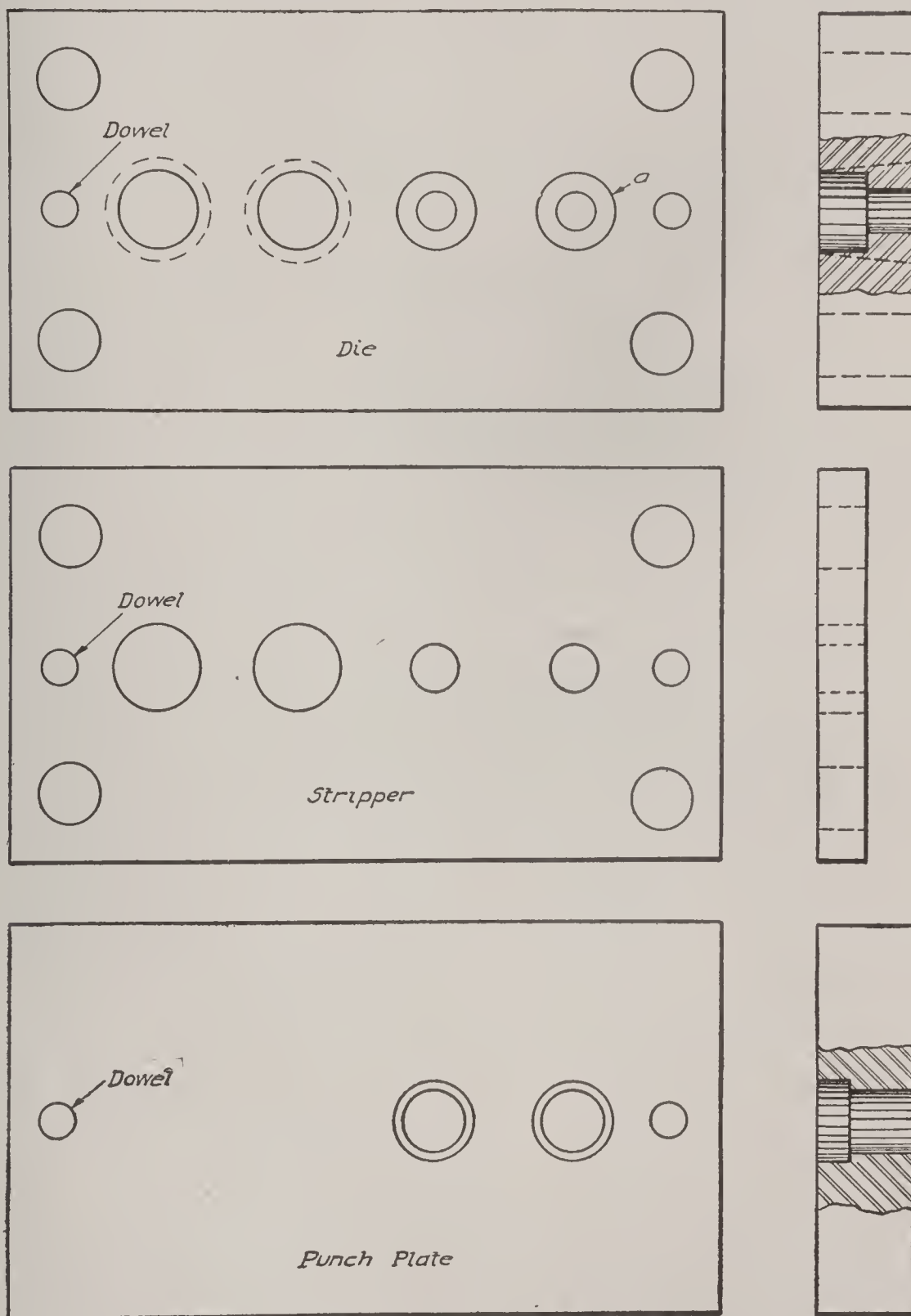


Fig. 38. Diagrams Showing the Die, Stripper, and Punch Plate

$\frac{1}{8}$  inch larger than a No. 10 screw are now attached to the punch plate, as fully described in Tool-Making, Part II, Figs. 268 and 269. The object in using the button method is that the die-maker is enabled to measure with micrometers from outside to outside of buttons and can place the buttons to within a tenth of a thousandth.

When the die is removed from the lathe faceplate, the die, stripper, and punch plate are in the condition shown in Fig. 38. The piercing dies are recessed as at *a* on the die block in Fig. 38, for the reason that the diameter of the hole is given in thousandths, and should the holes be bored a trifle too large, the die would be practically ruined, otherwise. Also, it may be desired to change the diameter of the piercing dies, which can be readily accomplished by removing the bushings and inserting new ones having holes of the desired diameter.

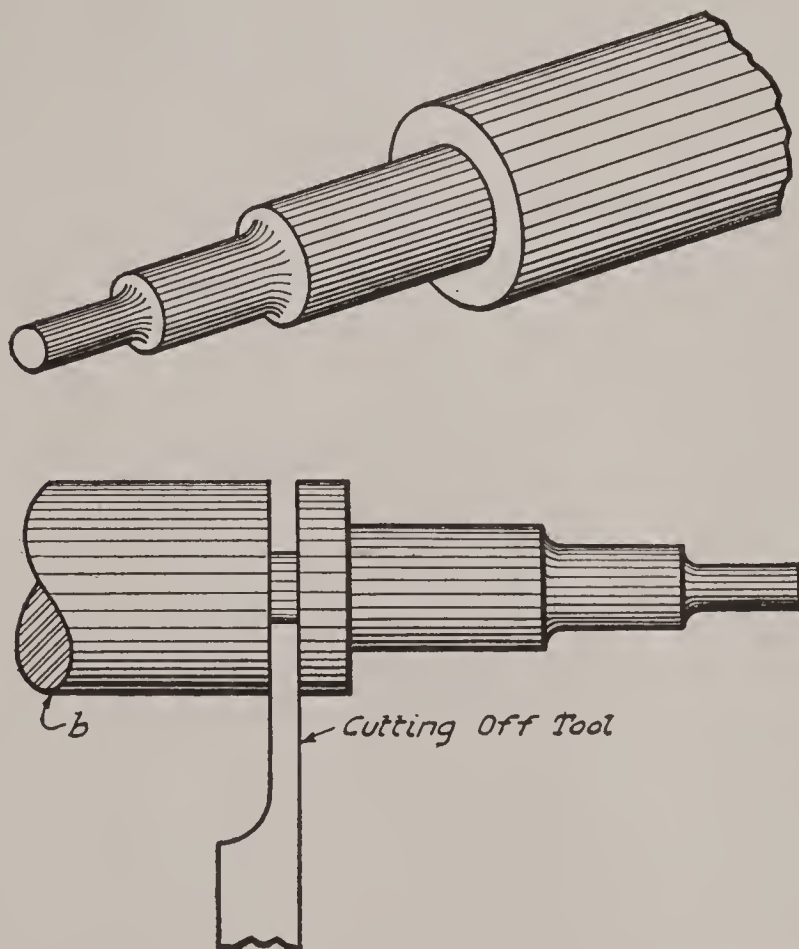


Fig. 39. Making Punches for Gang Dies

Referring to Fig. 38, it will be noted that the clearance had been bored in the ends of the blanking die. All that remains to complete this die is to carefully mill out the web between the two holes; or the web may be cut out using a hack saw, and the sides machined in a shaper which will insure good straight lines. The same precautions relative to screw holes and hardening as already described must be fol-

lowed out on all dies. The stripper is machined out in the same manner.

*Punches.* The punch plate is set on the die, care being exercised that the proper side is placed against the die and that the punch holes line up approximately with the die holes. The outline of the die is now scribed on the punch holder in order to find the approximate location of the blanking punch. The blanking punch is preferably turned with a shank, and a hole is drilled and reamed through the punch plate for a tight fit on the punch shank.

The piercing punches must be made, hardened, and ground, if necessary, and inserted in the punch plate before the blanking

punch is made, for the piercing punches, being left somewhat longer than the blanking punch, are used as guides to positively locate the blanking punch over the blanking die. If the punches are to be ground, they can be turned upon centers, or can be made as in Fig. 39, and the piece that is held in the chuck is left on the punch and serves as a holding means when grinding. After the punches are ground, the soft end can be cut off as at *b*, Fig. 39. Punches made with a head are easier to make without centers, and, as the

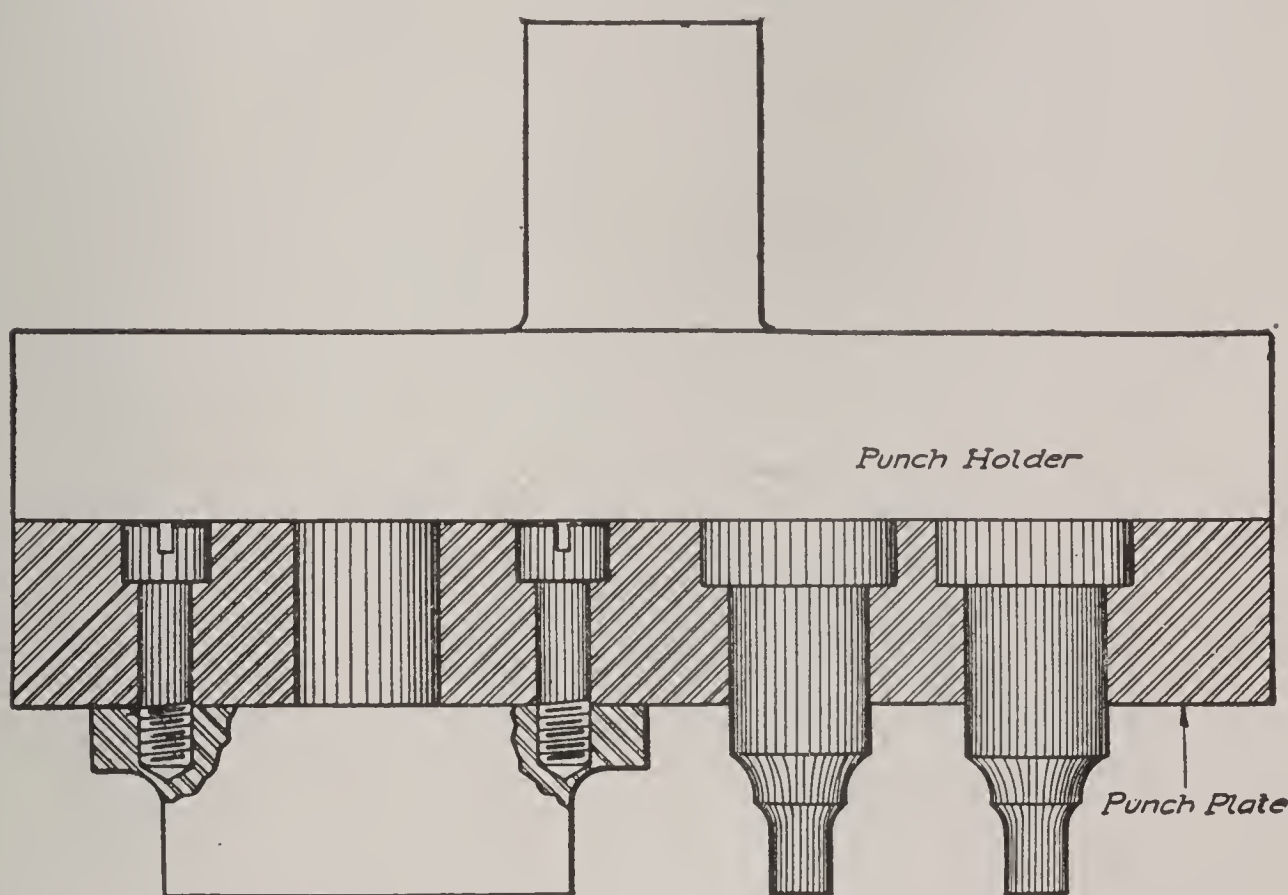


Fig. 40. Method of Holding Punches and Blanking Dies

punch plate is attached to the punch holder as in Fig. 40, the punches cannot push out or pull out.

Having inserted the piercing punches and the blanking punch in the punch plate, a dowel hole is now drilled and reamed lengthwise of the shank, as in Fig. 41. The hole should be drilled so that three-fourths of the diameter of the dowel pin is in the punch plate. A well fitting dowel pin is driven in this hole and the punch is ready to lay out. Upon entering the piercing punches in the piercing dies the face of the blanking punch comes in contact with the face of the die, in which position the outline of the die is scribed on the face of the punch. The blanking punch is now driven from the punch plate and milled to the line, beveled, and returned to the punch

plate to start the first shear, being guided by the piercing punches which, being longer, of course enter before the blanking punch comes in contact with the plate. After the blanking punch has been forced in a short distance, the punch may be removed, or may be finished while in the punch plate, as suits the fancy.

Pilot pins to enter the holes pierced in stock must be placed in the blanking punch and must be exactly the same center distance apart as the piercing dies, or else the holes will be distorted when blanking. In this particular die a thin disc 1 inch in diameter may

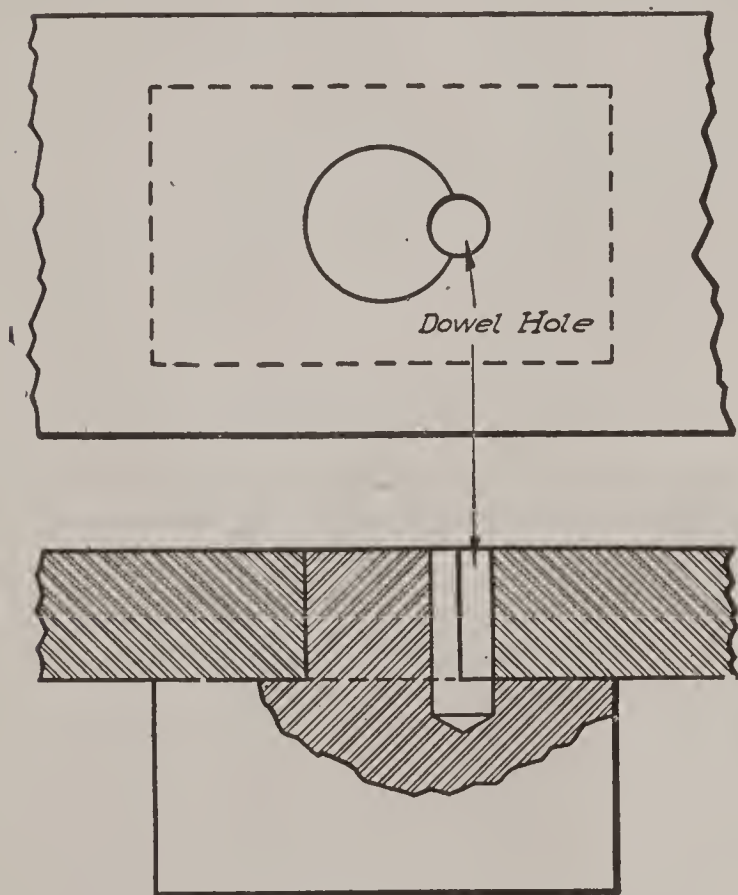


Fig. 41. Method of Drilling Dowel Hole

be turned on the end of a rod held in a lathe chuck, and, at the same setting to insure concentricity, a hole drilled and bored to fit a standard drill. The disc is then severed from the bar and may be clamped to the face of the punch so that the edge of the disc is exactly in line, or even, with the end of the blanking punch. The drill, since it fits the hole, drills the holes very close to the exact distance from the ends and the side of the punch. These pilot holes must be drilled clear through

the punch, as the pilots are driven out when grinding the punch. The pilots are made with a shoulder and tempered to a dark blue, and, when the punch and plate are assembled, they appear as in Fig. 42.

*Proper Sequence.* The reason that the piercing punches are made and inserted first is that the piercing-punch holes were already in the punch plate, and, if the blanking punch were fitted to the die without the piercing punches being entered in the die, the piercing punches would not line up with the die. Whether the punch plate is bored at same time as the die, or not, the piercing-punch holes should be the first to be bored, and the punches should be used as guides. It is readily seen that to transfer the holes from the die to

the punch plate while the blanking punch is entered in the die means that the punch plate is some distance from the die, and to transfer the piercing holes would mean that the punch plate would have to be parallel with the die and that any transfer drill used would only be guided by a thin edge of the tapered piercing die—altogether making an unsatisfactory and unworkmanlike method, although this haphazard method is practiced by many so-called expert die-makers. When punches are located in this manner, it always happens that the punches do not quite line up and must be sprung over, if slender,

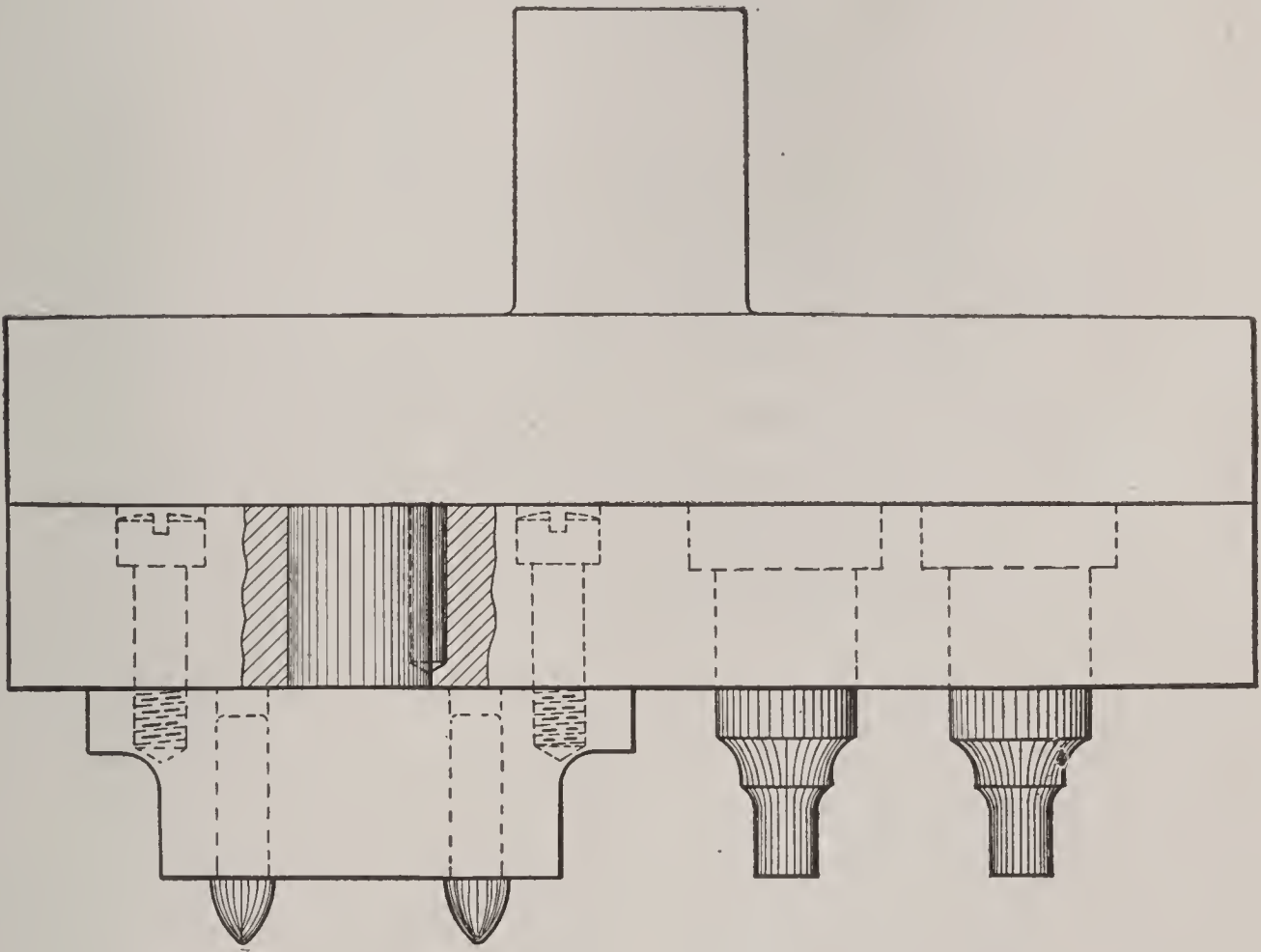


Fig. 42. Piercing and Blanking Punch Complete

and if too large in diameter to spring, the punch-plate stock surrounding the punch is swaged in order to crowd the punch over. Always use that method which contains the least number of chances for error, for, besides distinguishing the expert, it saves time in the end.

### SHEARING DIES

**Two-Punch Principle.** The cutting action of dies termed shearing dies is similar to the action of shears, from whence they derive the name. When in use one part is placed in the punch holder and is called the punch, while the other half is attached to the die shoe

and is called the die, although in reality both members are punches. Shearing dies in their simplest form are used to cut pieces from

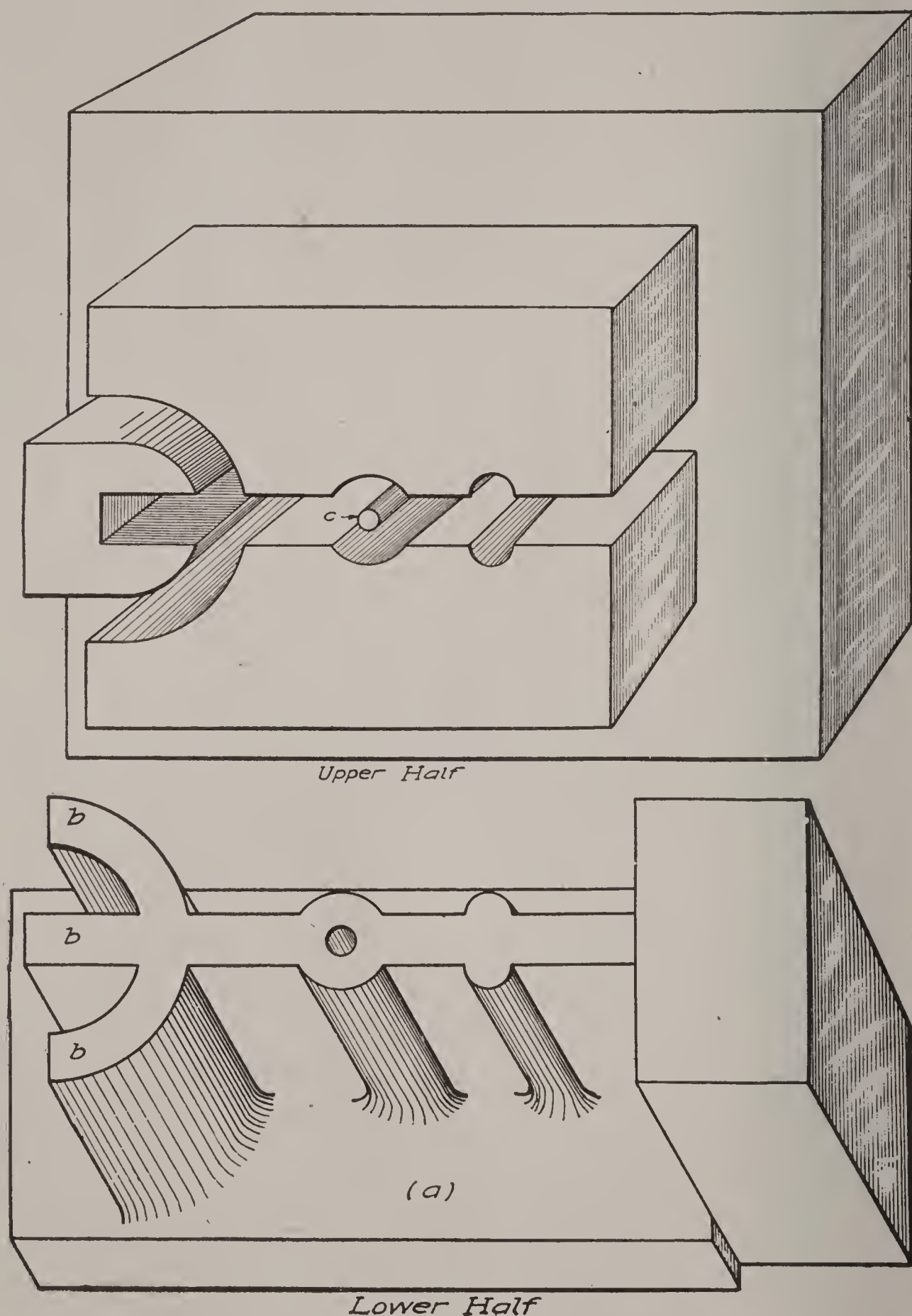


Fig. 43. Punch and Die Which Cut the Stock Away Leaving Blank Temporarily on the Strip strips or bars, but the shearing or two-blade principle has been so elaborated upon that the most economical type of die is that employing the two-punch principle.

*Advantages.* Fig. 43 shows a plain type of die employing the two-punch method, and it will be noted that the method of obtaining the blank is directly opposite to that when a punch and die is used. An ordinary punch and die cuts the blank from the strip, while the type shown in Fig. 43 cuts the stock away, leaving the blank temporarily on the strip. This has many advantages. The blank can

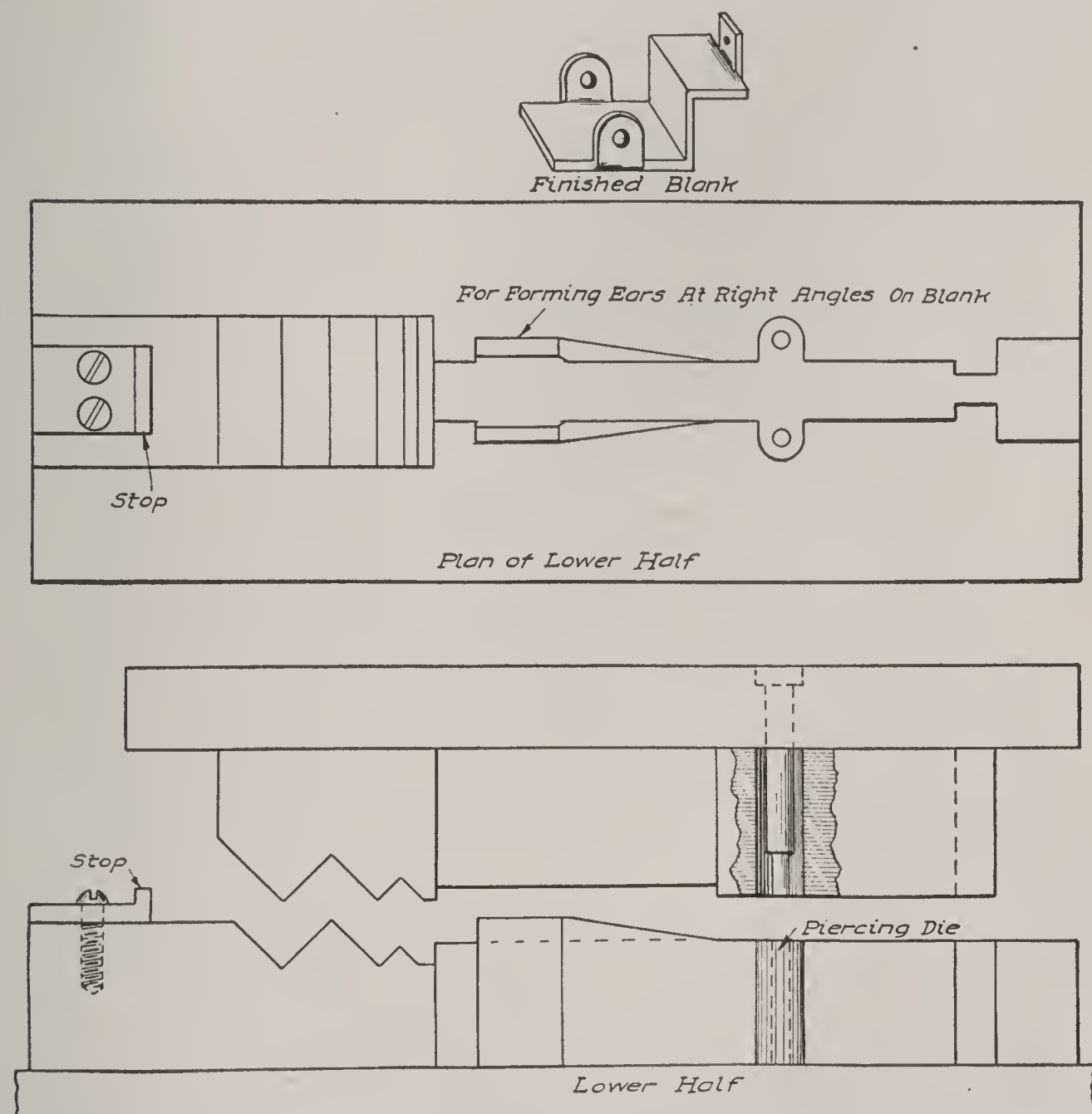


Fig. 44. Two-Punch Die with Formed Ears on Finished Blank

be put through a number of bending, drawing, or forming operations, and when finally completed the blank is severed from the strip by the shearing punch. This type of die also saves considerable stock, as the margin on the edge and the web necessary between the blanks when using a blanking die is eliminated. Fig. 44 shows a side view of the same type, elaborated upon to the extent of forming several ears before severing the finished blank.

**Making Lower Punch. Strains.** The first piece of the die in Fig. 43 to be made is lower punch *a*. It will be noted that the punch is not machined the same shape its entire height but that a supporting plate is left on the bottom. This plate or shoulder should be left on all punches that have long ears as *bbb*, for, without the plate, the ears would spread apart or spring together during the hardening process.

Another precaution that should be taken when making either a blanking die or a punch having long slender ears, as in Fig. 43, is to machine the steel all over to remove the scale, then slowly heat to bright red, and pack in lime to insure slow cooling and also to prevent

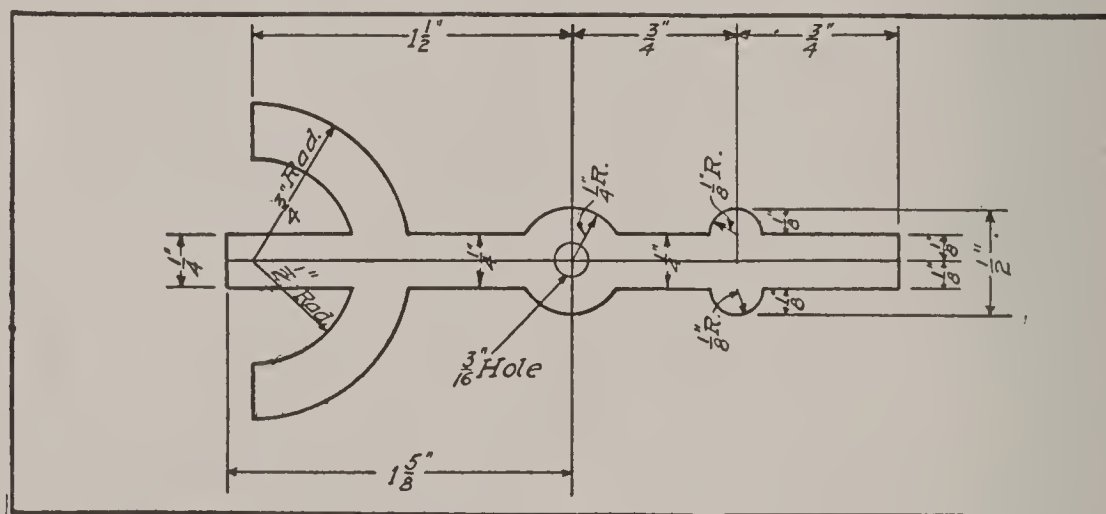


Fig. 45. Sketch of Lower Punch of Die Shown in Fig. 43

oxidation to a great extent. The object of annealing is to remove the strains in the steel.

**Laying Out.** Having machined all over and blued the surface of the block for the punch, center lines are scribed lengthwise or crosswise of the punch block. Referring to sketch Fig. 45, the first dimension at the right of the cross-center line is  $\frac{3}{4}$  inch, therefore, a cross-line is scribed  $\frac{3}{4}$  inch from the center line by means of either the height gage or surface gage, or by measuring with a scale and sliding a square along the block until the blade touches the scale. The block should now look as at *a* in Fig. 46. The next dimension to the right of this line is also  $\frac{3}{4}$  inch, so the operation is duplicated, and the die block looks as at *b* in Fig. 46. Starting at the cross-center line the shortest dimension at the left is  $1\frac{1}{2}$  inches, *c*, Fig. 46, and when this line is scribed on the punch the  $1\frac{5}{8}$  dimension line *d*, Fig. 46, also is scribed crosswise. Before going further, each space

between cross-lines is carefully measured and checked with the dimensions on the sketch. The radius around the center hole calls for  $\frac{1}{4}$  inch. Setting divider points  $\frac{1}{4}$  inch apart, the circle is scribed as at *e*, Fig. 46. The large radius calls for  $\frac{3}{4}$  inch, and is struck from a point  $1\frac{5}{8}$  inches from the center and on the center line. As we already have this location, the divider points are set  $\frac{3}{4}$  inch apart and a circle is scribed as at *f*, and from the same point the  $\frac{1}{2}$ -inch radius is scribed. Also from the same point there is scribed a  $\frac{1}{4}$ -inch

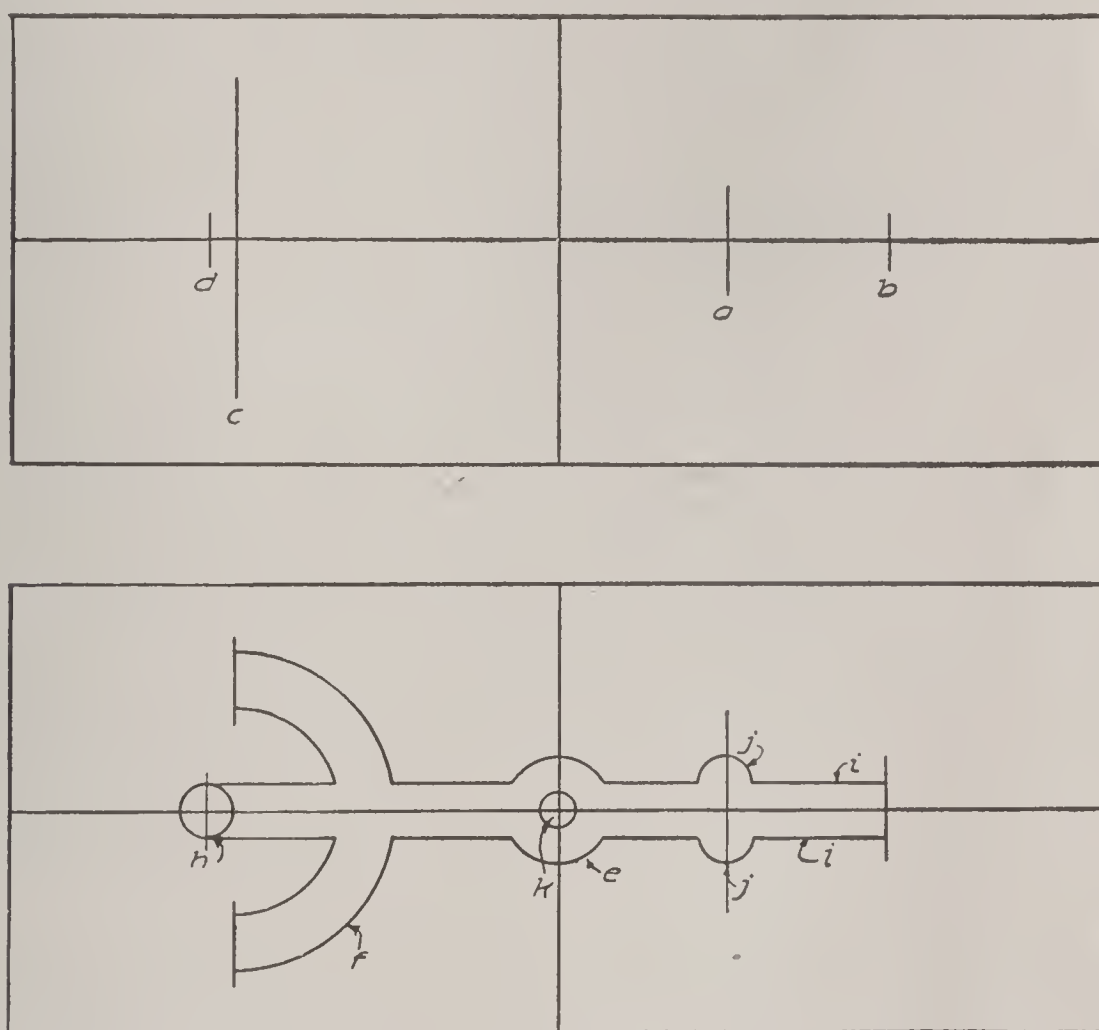


Fig. 46. Layout of Punch on the Block

circle *h* which is the width of the bar. Using a surface gage or a height gage the two lines *ii* are drawn on the punch block. The two  $\frac{1}{8}$ -inch radii *jj* are now scribed, completing the outline of punch. The  $\frac{3}{16}$ -inch circle *k* for the hole is scribed, and the punch is ready to machine.

*Piercing Die.* A small prickpunch mark should be made in the center of the circle for the hole, and a small drill, say a No. 50, that is well sharpened and which runs true when gripped in the drill-press chuck is first used to drill a hole say  $\frac{1}{4}$  inch deep. The object in

using the small drill is that the tendency to climb out of the prick-punch mark is reduced to the minimum, then, when using a larger drill to size the hole, the point of the large drill is more apt to follow the small hole.

To indicate a hole in a job of this character would be a false attempt at accuracy due to the fact that the outside of the punch will be machined to a line. If, however, the dimensions are in thousandths, then the hole should be indicated and bored, and the  $\frac{1}{2}$ -inch outside diameter  $e$  could be machined at the same setting while the punch is strapped to the faceplate of the lathe. To complete the outside diameter  $e$  in the lathe, however, would require a splining tool and that light chips be taken by sliding the carriage of the lathe back and forth.

The sides of the lower half must be straight, for the lower half is used to shear the upper punch parts.

*Hardening.* In hardening the lower part it should be placed in the furnace face down, and when dipped in the bath the face should be the first to enter and a slight up-and-down motion should be kept up until the punch is hardened. The base or flange should not be hardened. The object of keeping the punch in motion while in the bath is to prevent a crack or bulge which would take place if the punch were placed in the bath and held at one point. Where the water line comes on the punch there will invariably be a crack. A better way to heat a punch of this character is to heat it by immersing in a bath of red-hot lead.

*Surfacing.* After hardening, the face of the punch should be ground to insure a good sharp cutting edge all around, which is an aid when transferring the outline to the upper half. The back of the punch is now ground parallel with the face of the punch. This should be done by placing the face directly on the bed of a surface grinder and holding the punch to the bed with wax applied with a heated soldering iron. A suitable wax for this purpose consists of the following parts by weight: beeswax 7; resin 2; shoe-maker's wax 1. It is obvious that, when two surfaces are to be parallel, great chances for errors are experienced in gripping the work in a vise, and, after machining one surface, in gripping the work again for machining the opposite side. Always work from one face to another when possible, and, if the work requires **extreme** accuracy

as regards parallelism, a cast-iron plate or a piece of steel somewhat larger than the piece of work to be machined is waxed to the bed of the grinder or shaper and the surface made smooth and true by light cuts.

We now have a temporary bed that is absolutely parallel with the line of travel of the shaper ram or the V-ways of the grinder. The piece of work is now in turn waxed to this temporary bed and one side of the work machined and all wax removed from the work and the face of the temporary bed, then the work is placed machined face down on the temporary bed, and the other side is machined. This temporary bed can be also applied to lathe work by strapping it to the faceplate of the lathe, and truing the surface as a temporary faceplate; then strapping the work to this temporary plate the surfaces can be properly machined.

A magnetic chuck, a flat-topped box containing coils that become powerful magnets when current passes through them, is used extensively for holding flat work, but if the work is thin the wax should be used instead of the magnetic chuck, for the reason that the magnetic attraction is so great that a curved thin piece of work will be straightened against the face of the magnetic chuck, and if the surface of the work is ground or machined it is level until the current is turned off in the chuck and then instantly assumes its original curved state.

**Making Upper Punch.** *Transferring.* The lower punch is now finished, and its outline must be transferred to the punches of the upper part of the die. The small piercing punch *c*, Fig. 43, is the first punch to be permanently located in the punch holder and is left as previously described,  $\frac{1}{16}$  inch longer than the larger trimming punches. The large blocks for the trimming punches are attached to the punch plate by screws, and while dowel holes are placed in the punch blocks, the dowels are not put in until after the punches are hardened. Having attached the upper punch blocks in place on the punch holder, the piercing punch is entered in the piercing die and the lower part is positioned so that its edge is parallel with the edge of the punch holder of the upper part. In this position the two parts are clamped, the outline of the lower punch is scribed on the face of the punches of the upper half, and the punch blocks then are removed from the punch holder.

*Machining.* The face of a block is placed against the solid jaw of a shaper vise, and a rod, say of  $\frac{1}{2}$ -inch diameter, is placed between the movable vise jaw and the back of the punch. This insures the face of the punch being flat against the face of the solid jaw. If the rod were not used and the movable jaw should tilt slightly, as they invariably do, the work would be just as likely to lie flat against the movable jaw, which is then on an angle, as it would against the solid jaw, and the planed surface would not be at right angles with the face of the punch. By using a semicircular shaper tool the entire punch can be machined. For machining semicircles in the shaper, it is a good plan to turn up a disc, Fig. 47, and attach it to a tool for use in tool post. As the disc can be measured, it is much easier to obtain the proper radius by turning the disc than it is to file the radius tool accurately.

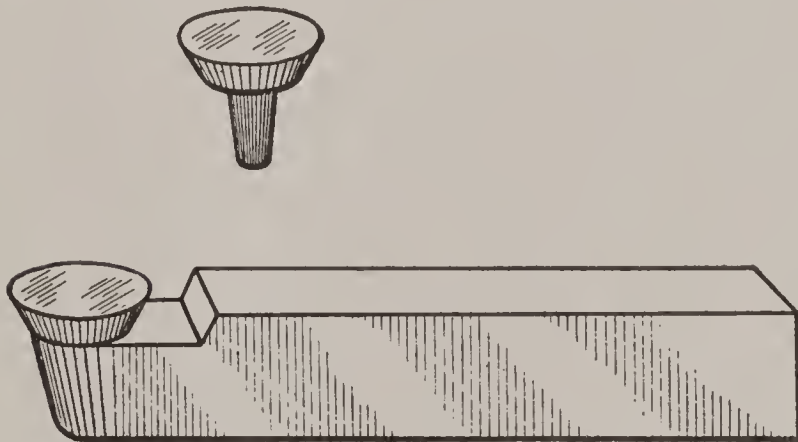


Fig. 47. Lathe Tool for Machining Semicircles

After all the punches of the upper half have been machined to the outline, they are then reassembled on the punch holder and the exact outline obtained by shearing. The object in leaving out the dowels until after the punches are finished and hardened is that, when milling or shaping to the line, too much stock might accidentally be removed, which would ruin the punch, but, as there is more or less play between the screw hole and screws, it is easy to move the punch over far enough to obtain a sheared outline over the entire contour. After shearing, say,  $\frac{1}{32}$  inch deep, the punch should be returned to the shaper and the surplus stock carefully removed until the shaper tool just scratches the sheared part. This operation requires great care and the machine should be run slower than for ordinary work.

*Locating on Punch Holder.* After smoothing and filing the punches with a fine file the punches are hardened and located on the punch holder, and, when firmly pressed against the lower punch, the screws are tightened in the punches of the upper half. The dowel holes are then transferred from punches to punch holder and the dowels inserted. The faces of the punches are ground by plac-

ing the back of the punch holder on the bed of the grinder. A stripper to work between the punches of the upper half is made of  $\frac{1}{4}$ -inch steel and is attached to the punch holder by screws surrounded by coil springs. The counterbored recesses in the punch holder are considerably deeper than the heads of the screws, so that as the stripper is pushed back the screw head can travel in the counterbored recess.

## DRAWING AND FORM- ING TYPES

### DRAWING DIES

#### Finding Size of Blank.

Drawing dies as a rule are very simple to make, as the majority of drawn work is round, which means lathe work. Assuming that dies for the drawn cup in Fig. 48 are to be made, the first step is to ascertain the diameter of the blank when in its flat state. The thickness of the walls or side of the cup determines the diameter of the blank. For instance, if the cup is to be punched from  $\frac{1}{16}$ -inch stock, and the side walls and bottom must be  $\frac{1}{16}$  inch after being drawn to a cup, the easiest way—if a sample cup is submitted—is to cut a round flat blank from same kind of metal and of the same

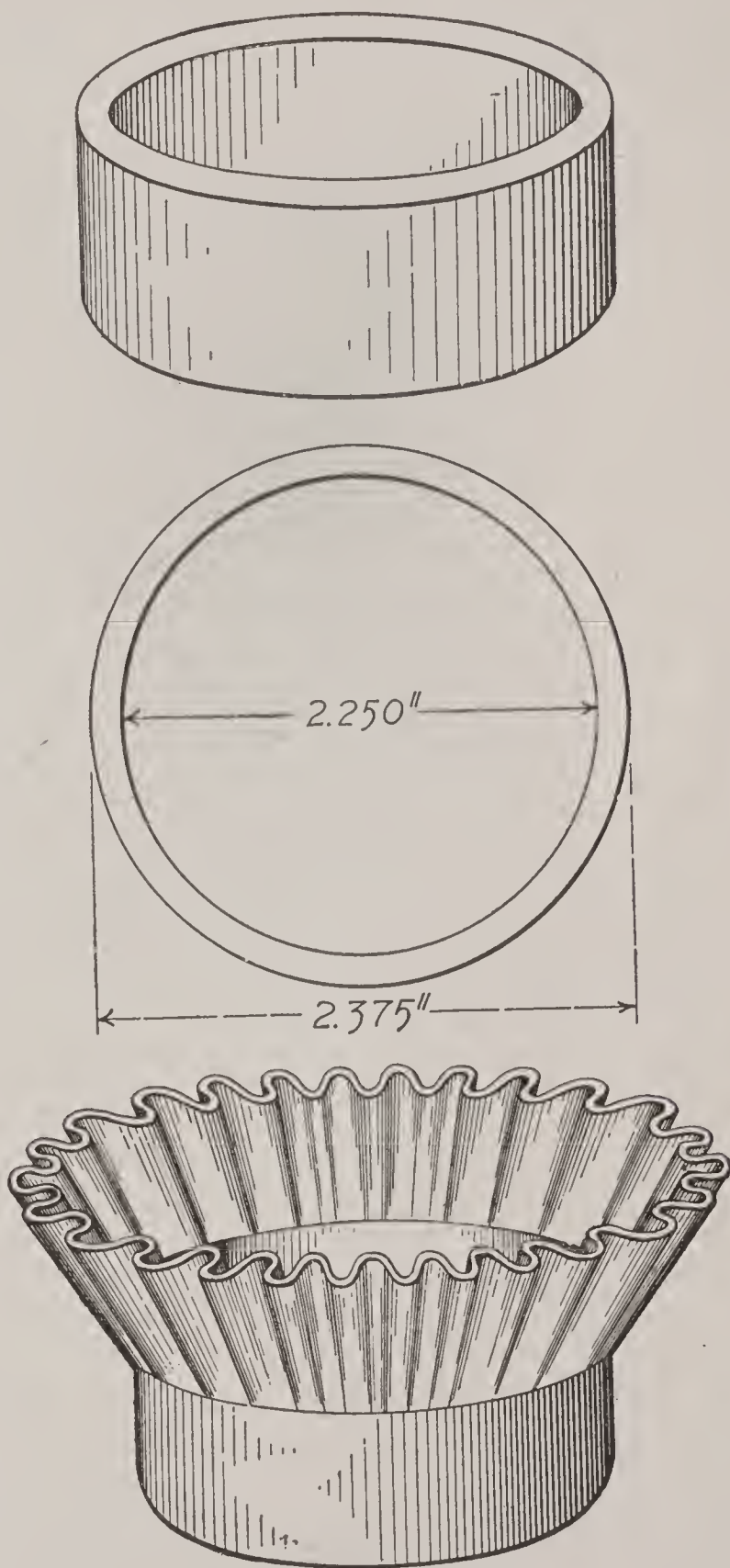


Fig. 48. Cup to Be Made by Drawing Dies

thickness and to keep reducing the diameter of the blank until it balances or weighs the same as the cup. Another way is to figure the area of the sides and of the bottom and to find the diameter of the blank having the same area. This latter method, however, is only approximately close, as the corners may be rounding in the cup making it difficult to figure.

**Types of Die.** In making the cup in Fig. 48, there are the following three types of forming dies that will produce it: (1) com-

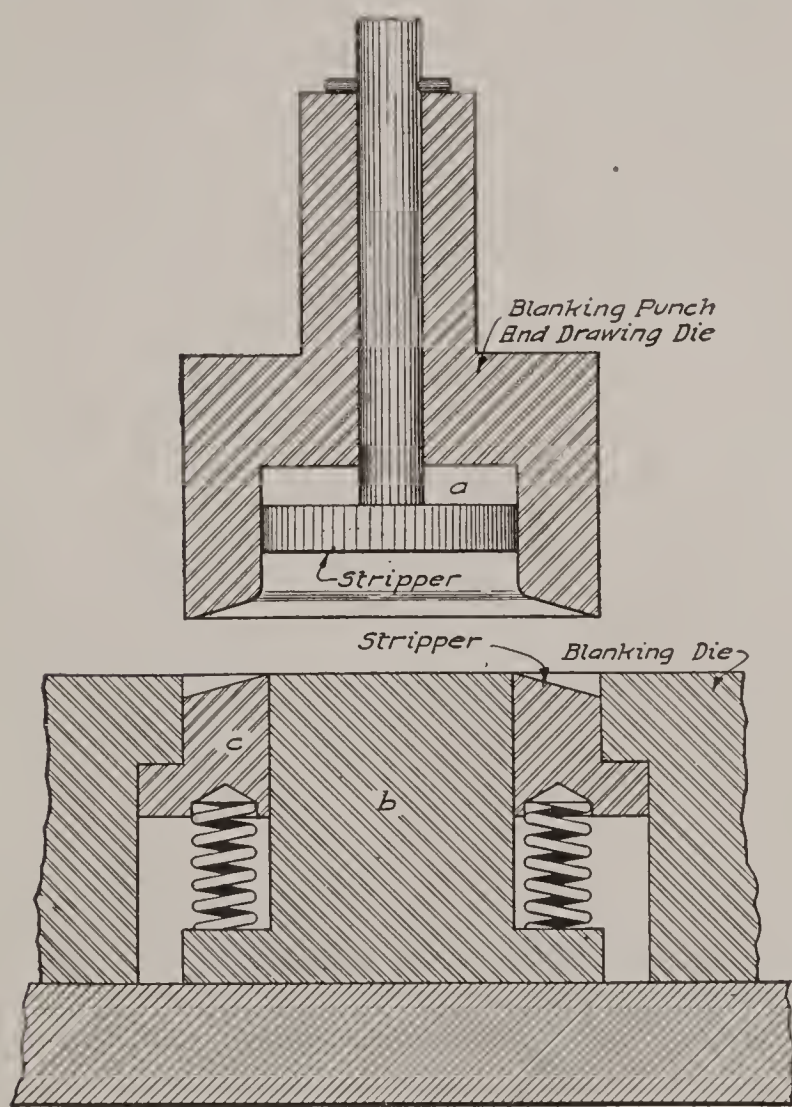


Fig. 49. Combination Punch and Die for Making Cup, Fig. 48

bination punch and die, Fig. 49, that punches out the blank and draws it to cup shape at one stroke in a single-action press; (2) combination blanking-and-drawing die, Fig. 50, for producing the cup in one stroke fitted to a double-action press; and (3) plain blanking die *a*, Fig. 51, and drawing die *b*, Fig. 51, which require two distinct operations, and this type of die can be used either in a single- or a double-action press.

**Making Combination Type.** *Blanking Punch.* To make the die shown in Fig. 49 the punch is turned up on centers or

may be made from the end of a bar held in a chuck. The size of the cup is  $2\frac{3}{8}$  inches outside. This means that the drawing die *a*, Fig. 49, which is in the blanking punch must be 2.375 inches when finished. As the punch is apt to distort in hardening, and also in order to present a better wearing surface, there is a sufficient amount of stock left on the outside diameter for grinding to size after hardening, and when turning, the inside *a* is left a trifle smaller in order to grind. The amount to leave, depends upon the size of the job

at hand; in this case .015 inch or .020 inch would be ample. Care must be exercised when turning and grinding to have the inside and the outside concentric. The outside is ground to the desired diameter, using micrometers, and, to measure the inside, vernier calipers or inside micrometers are used. The corners of the drawing die must be ground rounding so they are concentric with the die, and the corners must be highly polished to prevent the metal dragging when changing from the flat state to the cup.

*Drawing Punch.* The drawing punch *b*, Fig. 49, also must be ground to size, and care must be exercised that the punch is exactly the right diameter. If the drawing punch is left .002 inch larger in diameter than the die less double the thickness of stock, it would cause the stock to be compressed, which, in the drawing operation, would lengthen the cup. To save stock, the cup could be made the same height

using a smaller diameter blank, but the walls of the cup would be reduced in thickness; this means, of course, that the difference between the drawing punch and the die must be less than the thickness of the stock.

**Operation Points.** The points to be observed in drawing dies are: proper difference between the diameters of drawing punch and die; polished corners of punch and drawing die; and concentricity of inside and outside of drawing die and blanking punch.

*Stock Wrinkling.* The proper working of a properly made drawing punch and die depends upon the spring tension under stripper *c*, Fig. 49. If the tension is too great, the blank is held

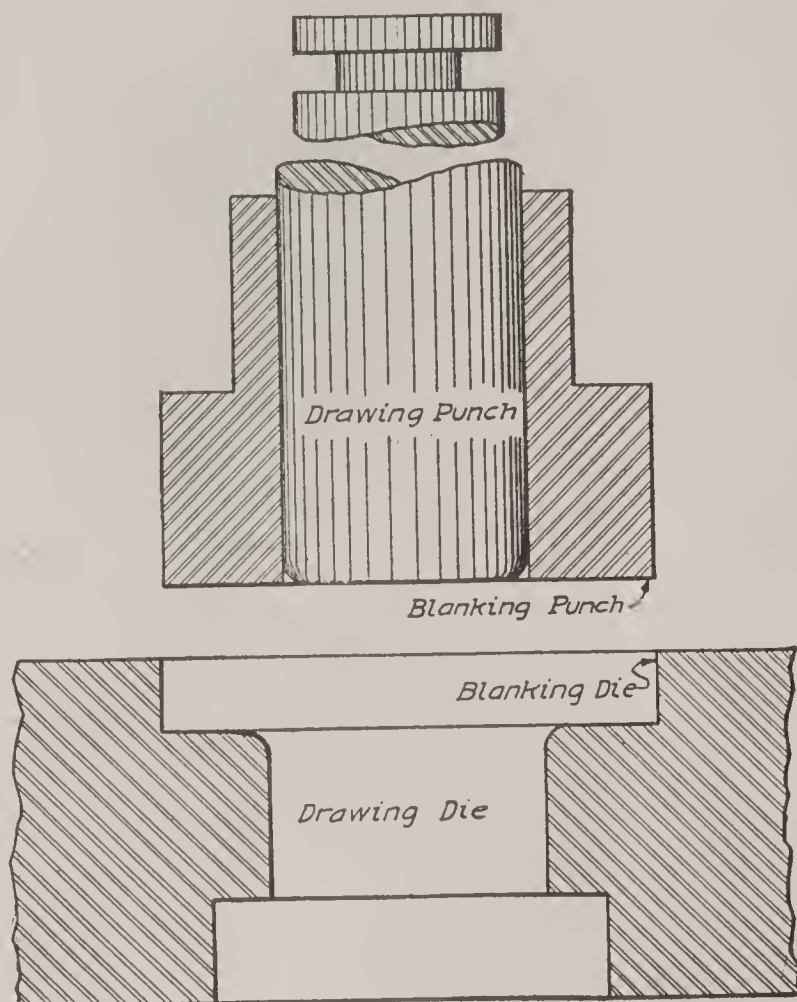


Fig. 50. Punch and Die of Combination Type

between the faces of the blanking punch and stripper which often causes breaks in the corner of the cups. Again, if tension is not enough, the stock when changing from a flat blank to a cup forces the stripper down, which causes a wider space between the stripper and the punch than the thickness of stock. This is the cause of

wrinkling of the edges of the cup as shown at *a*, Fig. 48. When wrinkles appear, increase the spring tension. Oftentimes the wrinkles overlap each other making a double thickness of stock to be crowded between the punch and the die where there is an allowance for only one thickness. This doubling of stock prevents the cup from passing through the die and as the punch continues downward the punch simply pushes the bottom out of cup.

The making of dies as shown in Figs. 50 and 51 is identical in operation with the foregoing description and the same points must be observed.

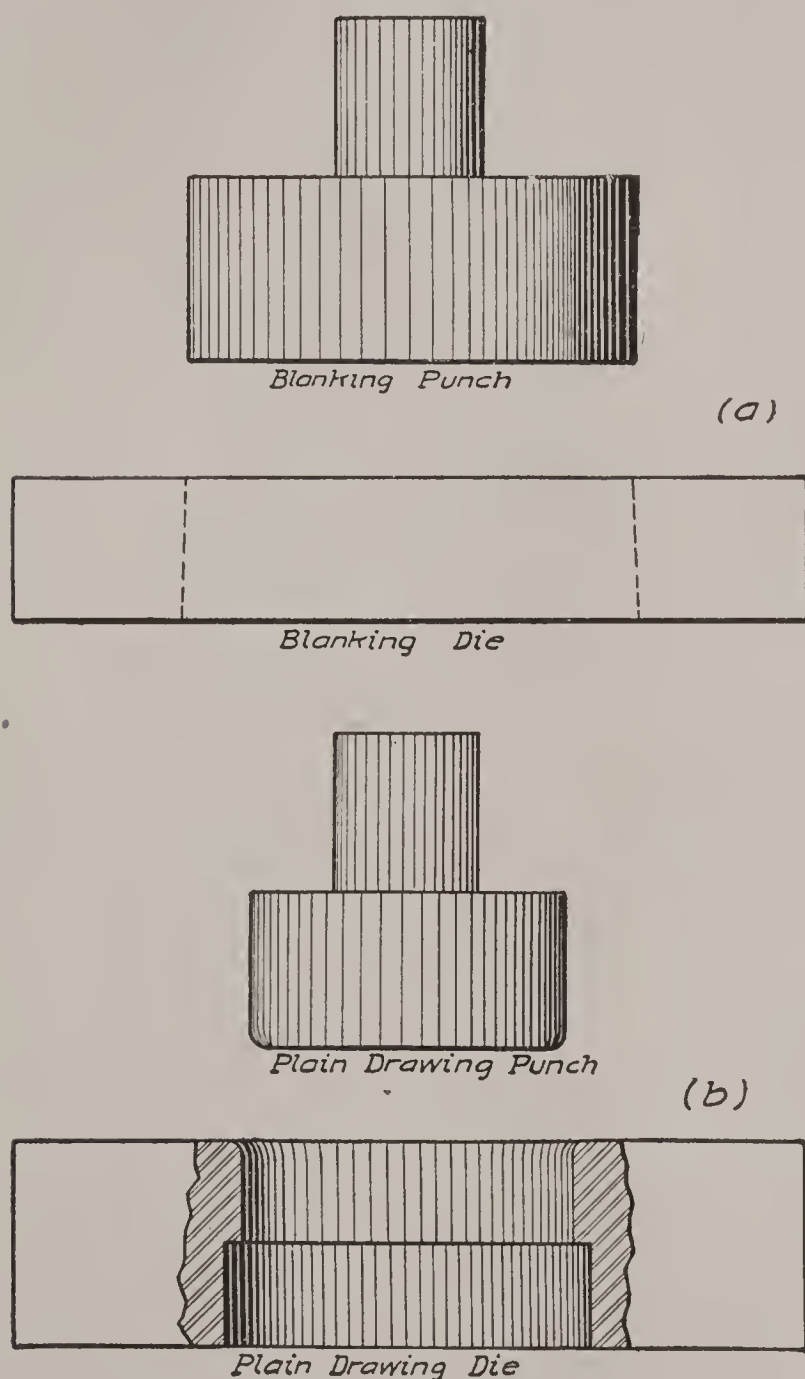


Fig. 51. Blanking and Drawing Punch and Dies Shown Separately

### Irregular Drawing Dies

**Method of Making.** Drawing dies for irregular shapes are seldom made to blank and draw at the same stroke, one reason being that the shape of the blank often has to be changed owing to variation in thickness and hardness of the stock to be drawn.

To make a drawing die to produce the cup shown in Fig. 52 requires about the same procedure as to make a blanking die, except that in the drawing die the sides or walls are perfectly straight. The first step also is to make the drawing die, for before the blanking die can be made, the shape of the blank will have to be found.

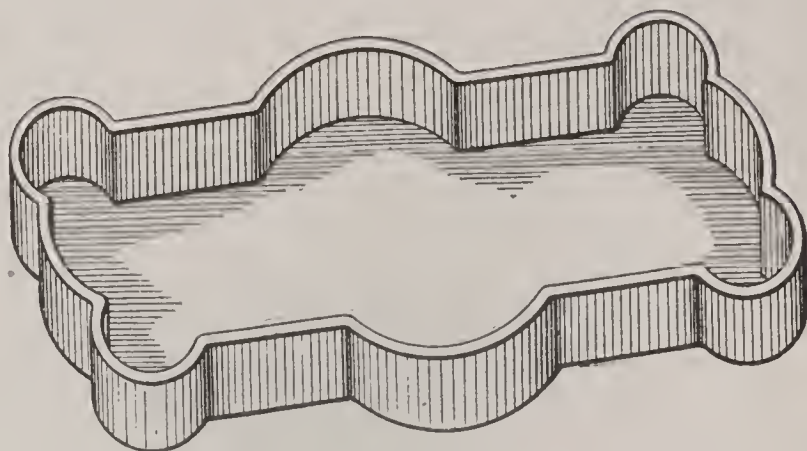


Fig. 52. Irregular Cup to Be Made by Drawing Die

*Punch.* The drawing punch in Fig. 53 should be made first. Assuming that the

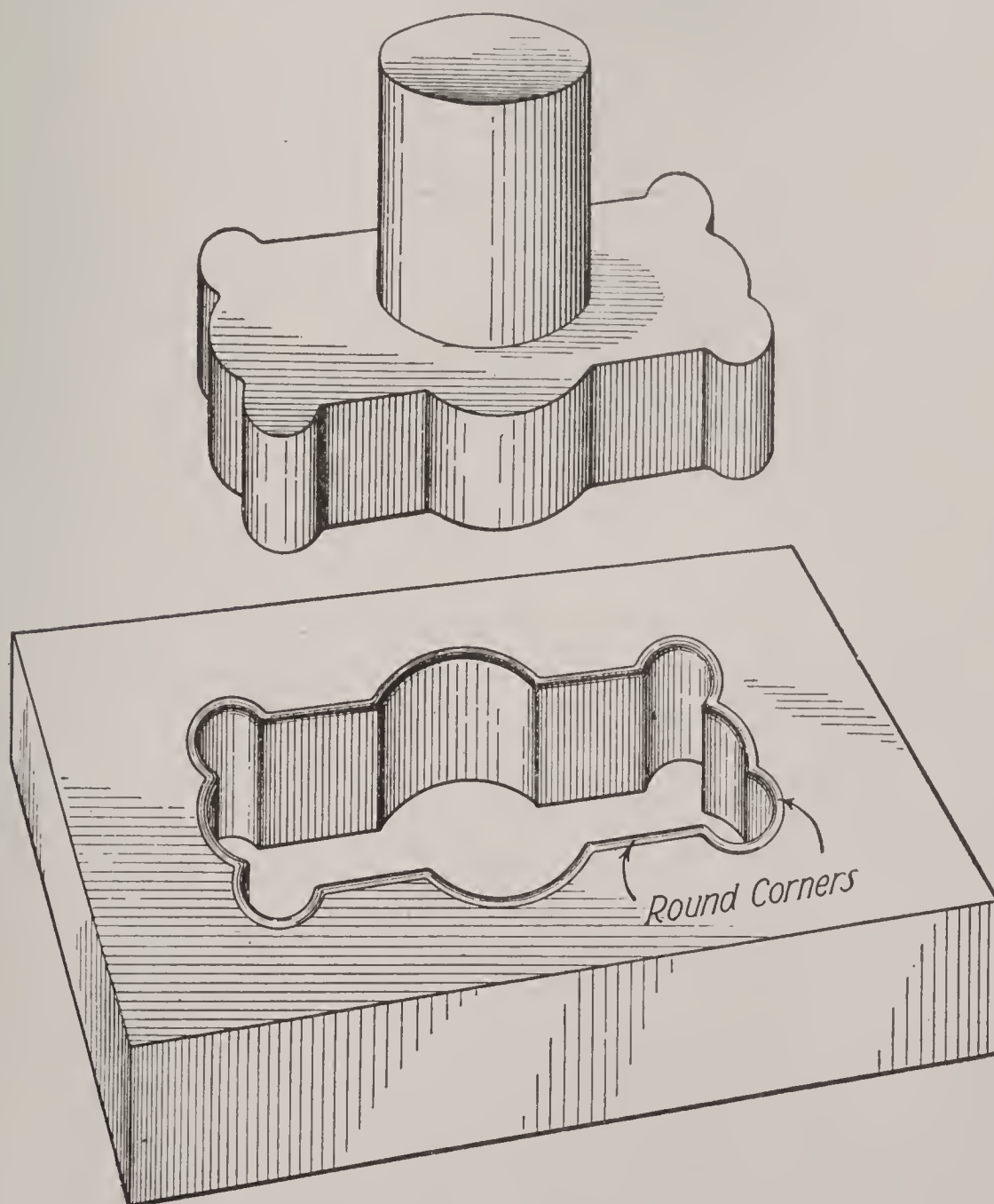


Fig. 53. Punch and Die for Making Fig. 52

punch has been machined to the overall size desired and has been blued on its face, we now lay out the outline on the face of the punch, and all lines on the punch face must be made from the same end and the same side. For instance, if the punch block in the rough state should not be parallel, and one line were scribed

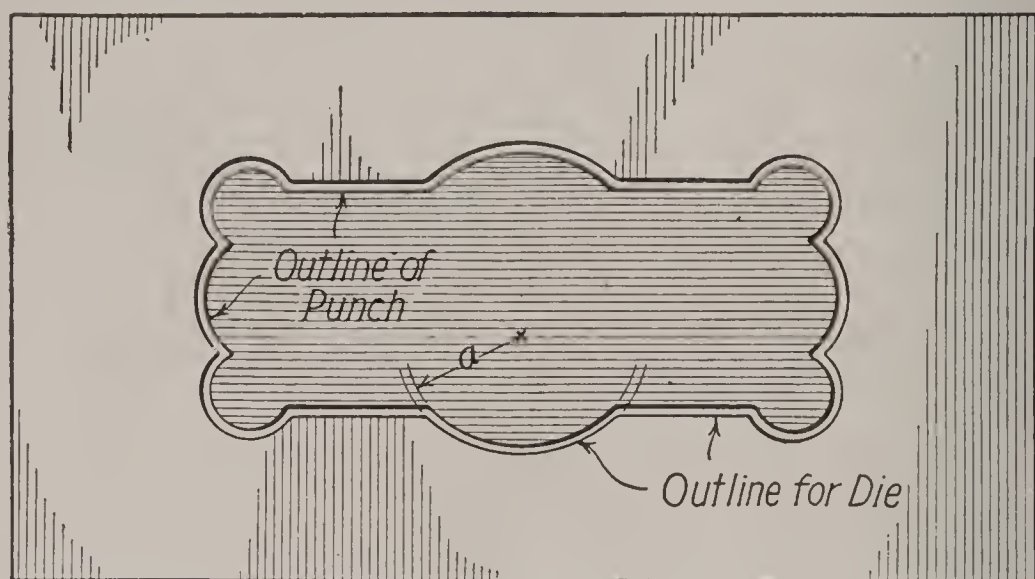


Fig. 54. Method of Outlining on Die Block

lengthwise of the punch from one side, then another line were similarly scribed from the other side of the punch, the two lines scribed would not be parallel. The punch should be machined between centers either on a miller or on a shaper.

The object in making the punch first is that its thickness and its length can be readily measured with micrometers, and when the

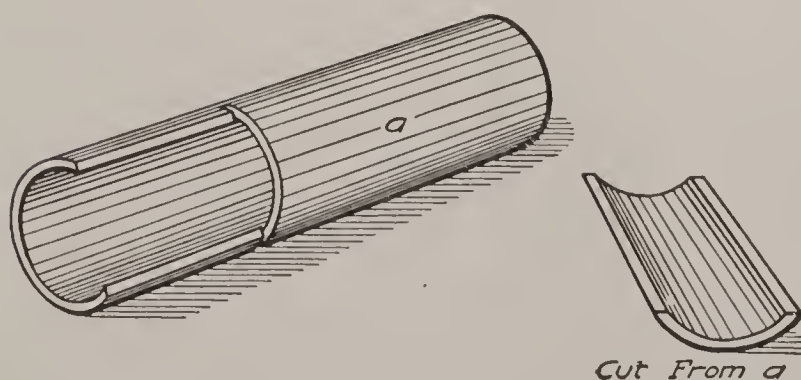


Fig. 55. Method of Determining Proper Size of Die

punch is finished its outline may be scribed on the die, then parallel lines may be scribed around this punch outline a distance apart from the outline equal to the thickness of stock, Fig. 54.

**Die.** The die outline is obtained by finding the radial centers of the circular punch outlines on the die, and scribing with dividers set as much larger as the thickness of stock, as at *a*, Fig. 54, then scribing the connecting straight lines. After machining the die nearly to the lines the punch should be used as a guide. By placing

the punch in the die, a piece of strip steel the same thickness as the stock to be used is inserted on each side between the punch and the die at the straight portion of the outline. For determining when the die is sufficiently larger a semicircular piece, Fig. 55, can be used; the semicircular piece being made by boring a hole in a piece of soft steel or brass the same diameter as twice the radius of the punch and turning the outside of the steel to a diameter of the desired die radius.

When sharp corners appear in the cup to be drawn, the die must have well rounded corners at the top gradually tapering to a sharp corner. If the cup to be drawn is of some depth, then two or more drawing dies are necessary. In this connection the draws are referred to as first, second, etc., and final. The first draw merely starts the cup to approximate shape, while the next draw makes the cup somewhat closer to finished shape, and the final draw completes the shape. Spring pads are used on practically all drawing dies.

### FORMING DIES

**Method of Making.** Forming dies, while very simple in design and to make, often present difficulties, inasmuch as the metal being formed does not always form up to just the shape of the die or the desired shape. The forming punch and die can be made exactly the shape desired in the blank but the metal may *crawl*—the shop phrase for metal going where it is not intended to go—or the temper of the metal may play an important part, and even after the forming punch and die are made to produce the desired blanks the next shipment of metal may be of a different temper and the die must be altered.

There are no hard and fast rules to lay down for forming dies, except to allow for the double thickness of stock between the punch and the die. The making of forming dies is a cut-and-try method. One point must be borne in mind—if dies to produce a formed piece are to be made, the forming punch and die should be made first in order to determine the exact shape of the blank from which the blanking die is made.

### EMBOSSING DIES

**Embossing.** Embossing means to raise a figure, or design, above the flat surface of sheet stock. In operation the best results are obtained from the blow by attaching the force, or punch, or male member of the die to the hammer of a drop press.

**Die Sinking.** There are three methods of making embossing dies, and to employ any of the methods the workman must be an artist, for the outline of the design must be transferred from a sketch or possibly from a sample to the face of the die—if the design is of a floral or landscape effect, it means freehand sketching to obtain the desired outlines on the die face. Embossing dies proper, as well as drop-forging dies, are distinctly apart from the work expected of tool-makers or blanking die-makers, and embossing die-makers are known as die-sinkers.

*Hobbing Methods.* The method most generally used is known as the hobbing method. A male member or hob is made, as in Fig. 56, which is for a suspender buckle, and when finished the hob is hardened and forced into the face of the die block. This operation

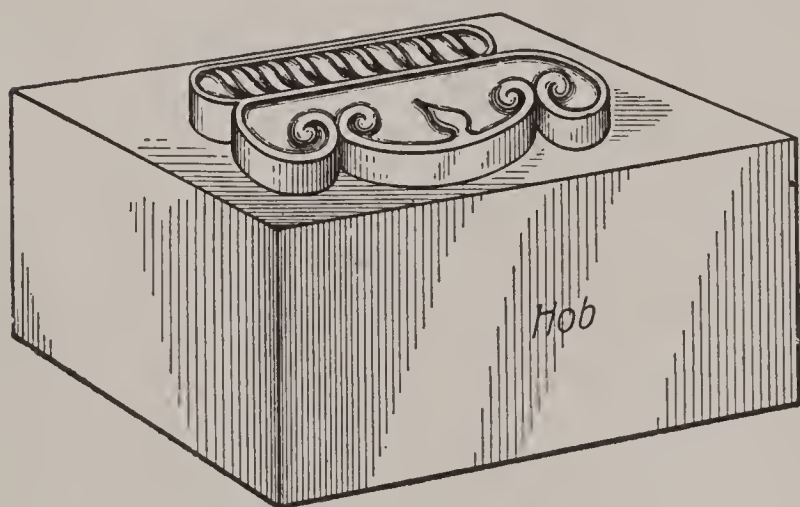


Fig. 56. Embossing Die on Hob

can be done either (1) cold, using hydraulic pressure, or (2) a flat-face punch can be attached to the hammer of a drop press, the die block heated to a bright red and placed in the drop press, and the hob placed in position on the face of the die block, the ham-

mer then being allowed to fall, and forcing the hob into the hot die.

When the latter method is used, however, the design as forced into the die block is rough, due to oxide scale from heating and cooling the die block. Also there is  $\frac{1}{8}$ -inch shrinkage per foot to molten steel, and the shrinkage of steel when only red hot is considerable. However, the rough design is in the die block, and with semicircular, diamond-point, and flat engraving tools the figure is finished and smoothed with die-sinkers' files called rifflers. The final polish necessary in an embossing die is obtained by using the end of a small stick of wood and loose emery; every part of the design in the die must be free from scratches, for any mark in the die will be transferred to the work.

*Reverse Cutting.* The third method is to cut the design directly in face of the die block. To do this the die-sinker must cut the design

the reverse of that desired, which is the most difficult method. Wax is used to obtain the impression. The surface of the die block or impression is smoked with a match to prevent the wax sticking and when the wax is forced into the impression in the die the wax shows

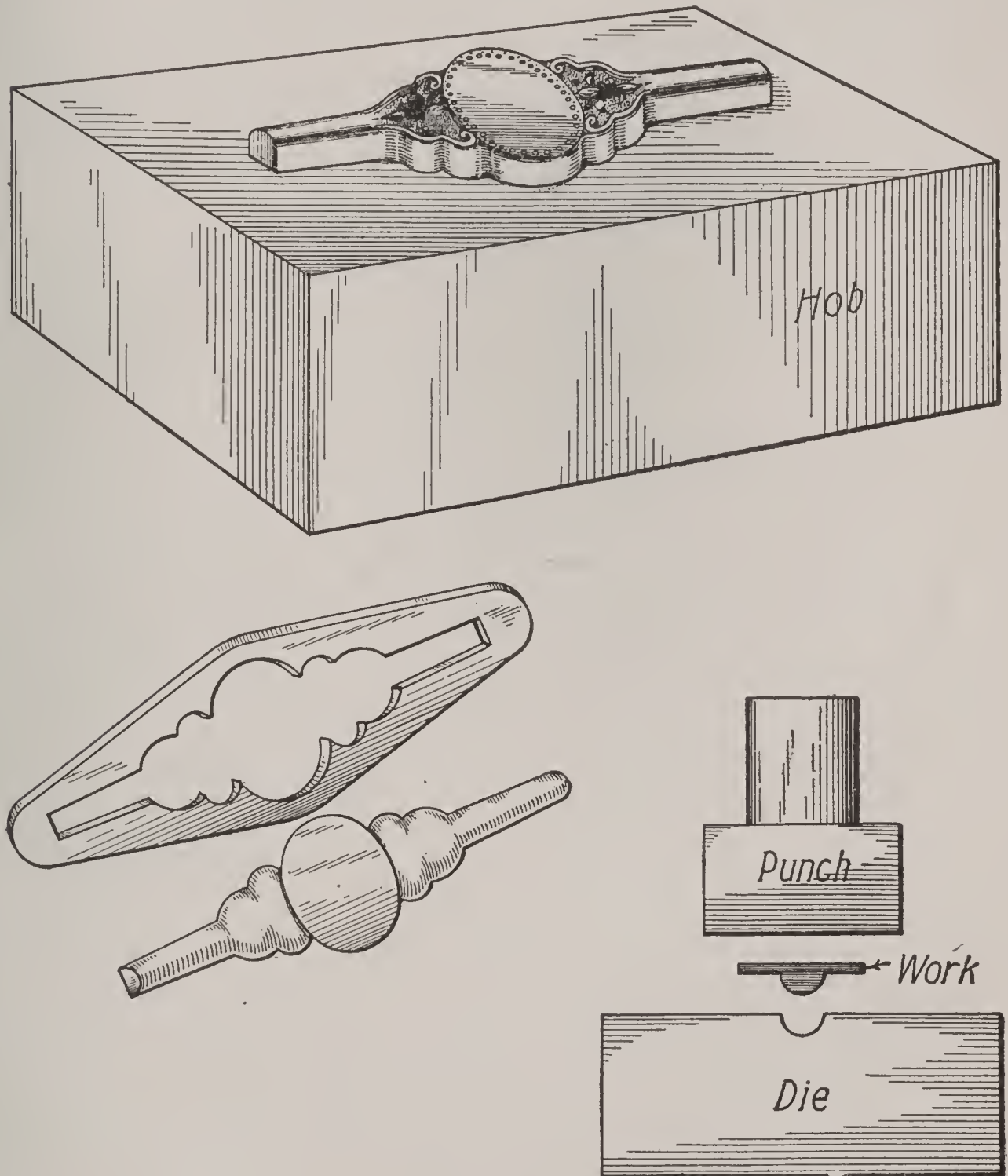


Fig. 57. Embossing Dies Used for Jewelry Work

the design and is the die-sinker's guide. The force or punch is made by shaping its end to practically the same outline as the depression in the die, and by forcing it cold into the die by hydraulic pressure, or the die may be fastened to the bed of a drop press and the force attached to the hammer and forced into the die, either hot or cold.

After a complete impression has been transferred from the die to the force the design on the force must be made smaller than the die to allow room between force and die for the stock to be embossed.

**Jewelry Dies.** Fig. 57 shows another style of embossing die which is used extensively for finger rings, breastpins, etc. The die shown is for a ring, and in operation the piece of gold is placed over the design in the die and a flat punch strikes the gold, forcing the design in on one side only. The piece of gold is then trimmed in a punch and die called a trimming die, which is nothing more nor less than a plain blanking die.

### FLUID DIES

**Usage.** There are many articles that can be formed by filling a cup with soapy water, placing the cup in a die, and allowing a punch—preferably in a drop hammer—to strike the contained water and to force the metal of the cup into the design of the die. Door knobs, watch cases, and umbrella handles are of the class of work that can be done profitably with fluid dies.

A power press is not suitable for forming with water as water will not compress and the travel of the press is so slow that, unless a perfect fit is made between the punch and the die, the water escapes and there is not pressure enough to force the metal. On the other hand, if a perfect fit is made between the punch and the die, the water acts as a solid mass, and the crank shaft of the press would be sprung, if not broken. Water for forming or embossing is only used when the forming takes place on the side of the cup, as shown in the pieces in Fig. 58. Any design or shape on the end of the cup could of course be done in a plain die and struck with a punch.

**Operation of Fluid Die.** Water forming dies, Fig. 59, are made in halves, one half stationary and the other movable, so that work can be removed after forming. Referring to *a*, Fig. 58, which is an umbrella top, it requires a cup formed as at *e*, Fig. 58, prior to forming in the fluid die. In operation a quantity of these cups in their plain state are placed in a pail of soapy water, the operator by moving the lever, *a*, Fig. 59, opens the fluid die, and, as a cup when removed from the pail is full of water, the cup is carefully placed in the die so as not to spill the water, and the die is closed. Generally a locking device is attached to the die to prevent its flying open when the punch strikes the water.

*Hammer Blow.* The height of fall of the hammer containing the punch must be determined by experiments on each type of blank. When the proper height is found that will give the full design on the cup, the press hammer is set so that the fall will be uniform for each blank. The hammer must also be a perfect fit

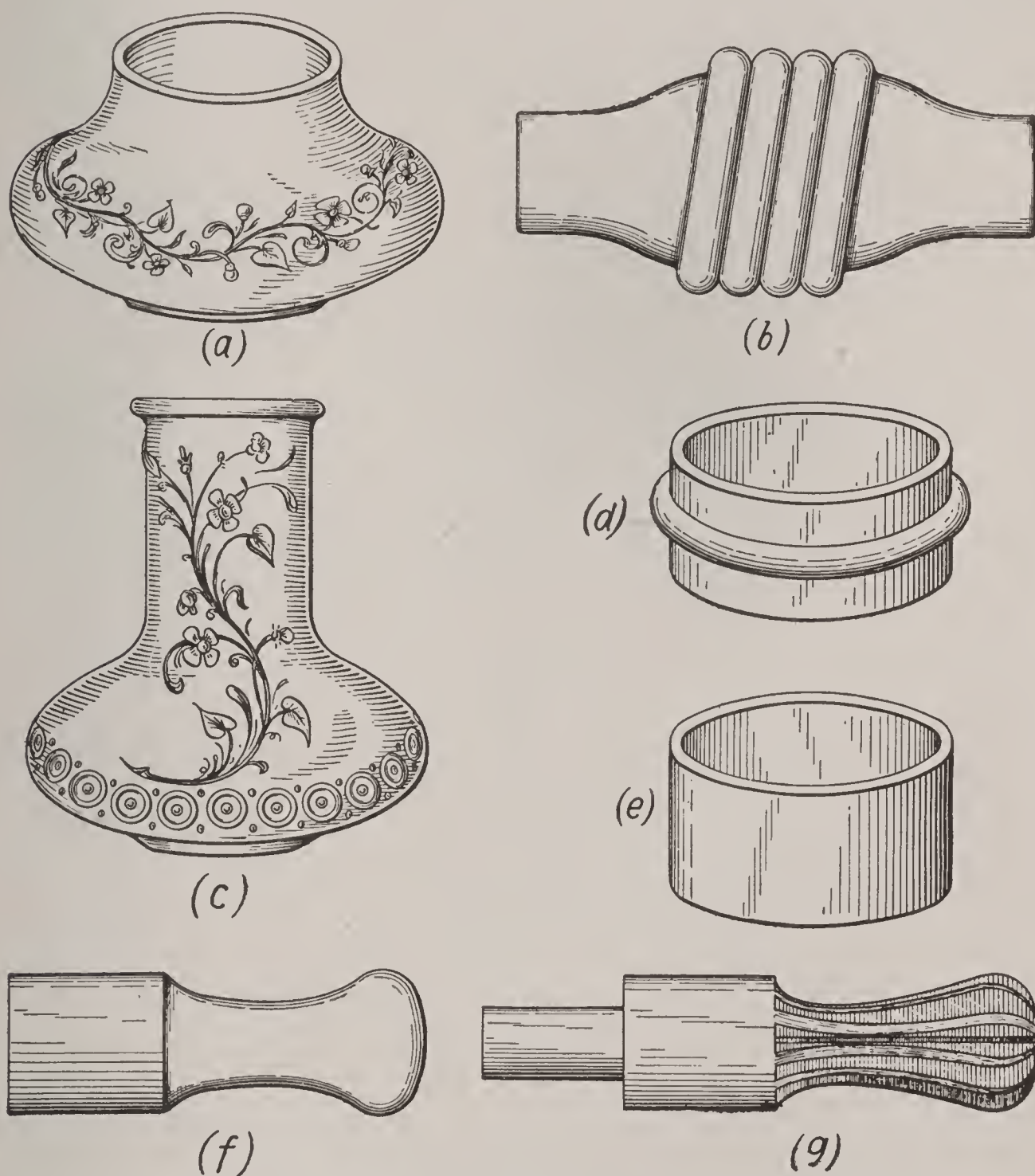


Fig. 58. Examples of Work Done by Fluid Dies

between the uprights or ways of the drop press, for the punch must fit the upper opening in the die to prevent the escape of water, and a loose hammer would cause the punch to strike on the corner of the die, not only breaking the corner and the punch, but preventing the full blow on the cup. Also it is dangerous to the operator, as

the small pieces that break from punch and die travel at tremendous speed.

It is noted that the design is cut in the die shown in Fig. 59, but this is not essential as the design can be rolled in the plain blank and the height or blow of hammer regulated so that the swell or enlarged diameter on the blank can be obtained without marring the design.

**Substitute Processes.** *Use of Rubber Core.* The piece shown at *b*, Fig. 58, is a handle, and to make this form a cup would require

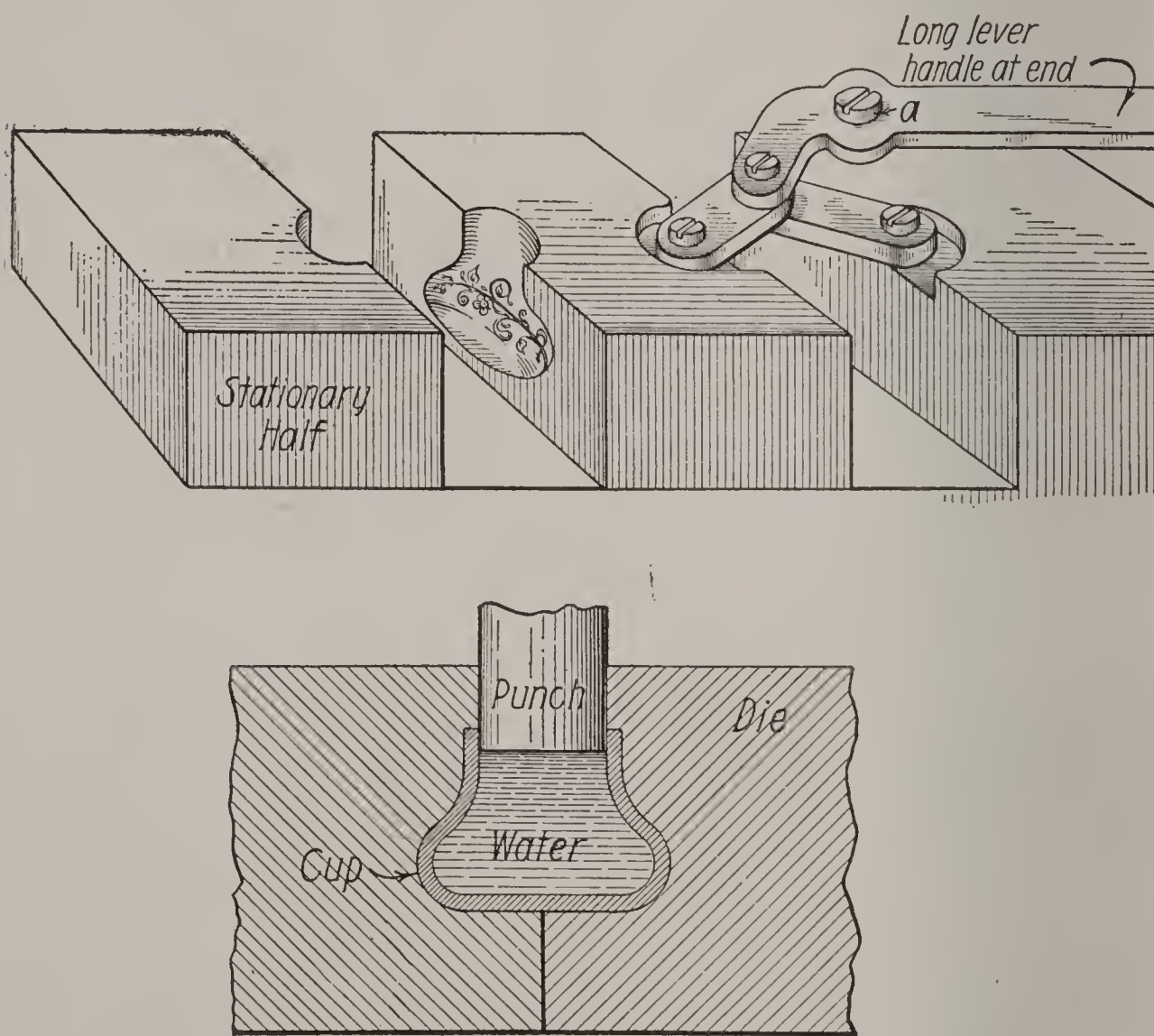


Fig. 59. Method of Operating Fluid Die

several redrawing operations and annealings before the cup was in the shape required for forcing in the design. A piece of tubing is cheaper, but as the tubing will not permit filling with water, work of this character having open ends is formed by placing a long bar of spring rubber in the cup after it is in the die. Rubber merely changes form but does not set, and when the punch strikes the rubber the rubber flows to the unsupported part of the tubing in the die which of course forces the tubing into the design in the die. The

rubber assumes its original shape as soon as pressure is relieved and it then is readily removed.

*Roller Dies.* The pieces *b* or *d*, Fig. 58, could also be made by the rolling dies in Fig. 60. The arbor *a* that the cup or tubing is placed on is considerably smaller than the inside of the cup or tubing, to allow the removal of the finished part. The female roll *b* is attached to the cross-slide of the rolling lathe or the roll dies can be used in an ordinary lathe by gripping the male member *a* in the

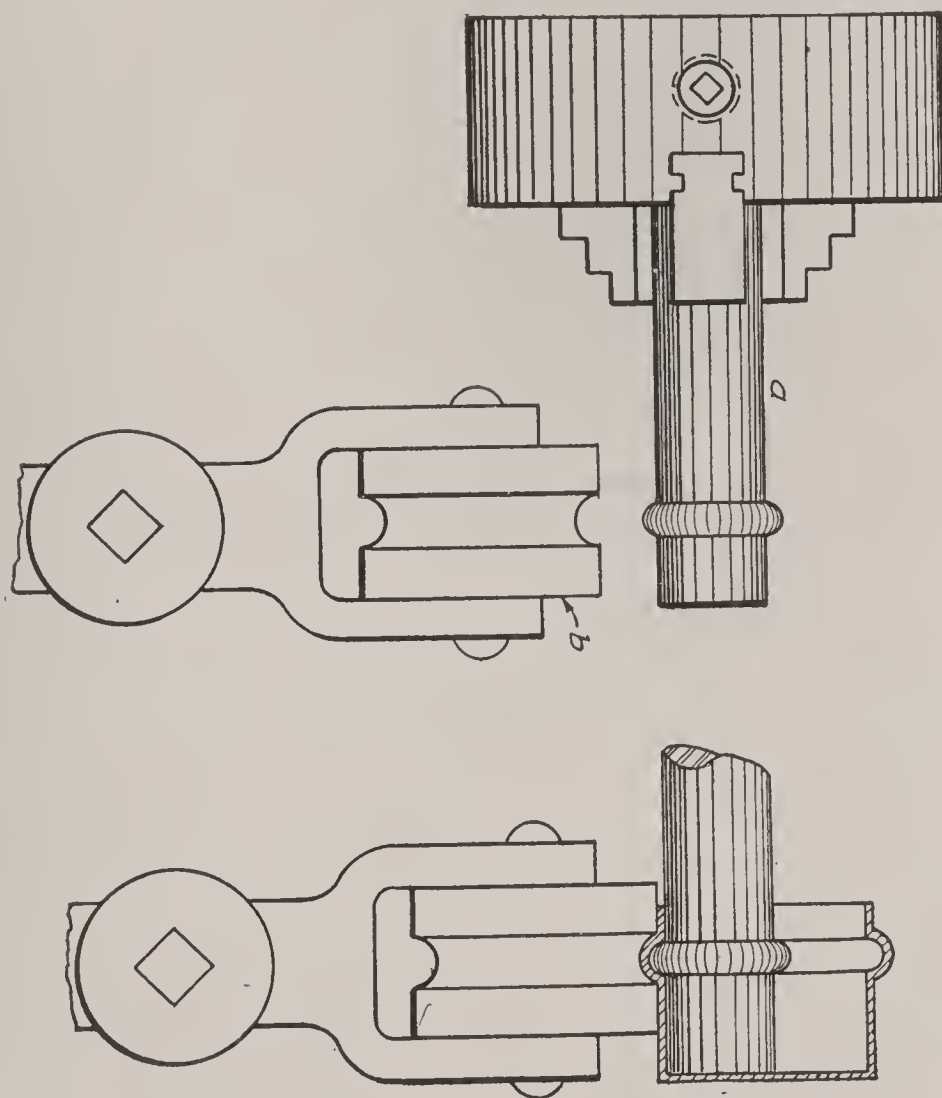


Fig. 60. Rolling Die

lathe chuck and the female roll in the tool post of the lathe. In operation the cup or tube is placed on the revolving roll in the chuck and the roll *b* is brought to bear against the work. The friction between the two rolls and the work is sufficient to cause the work to rotate, and as the cross-slide of the lathe is moved toward the center of the lathe the beading or form is transferred from the rolls to the work.

**Forming of Die.** *Locating Hole.* When making fluid dies the two halves are machined exactly the same height, and the faces

that come in contact with each other when the dies are together must be at right angles with the bottom. The two pieces are either screwed to a plate or attached to a special holder so that one half can be removed and replaced and the plate strapped to the face-plate of a lathe. A fine prickpunch mark is placed exactly on the line where the two halves meet and the prickpunch mark should be in the center of the two halves. If the prickpunch mark is indicated true, the hole will have half its diameter in each half of the die block; otherwise, one half will be of a greater diameter and trouble will be experienced in removal of the formed cup. The stock is removed in the usual way by spotting with a flat spotting tool, Fig. 61, rigidly held in the tool post to insure the spot being true, as the spotting tool actually bores or turns the recess spot which is to be the starting point for the drill that removes the stock. The angle of the spotting tool and the drill should be the same.

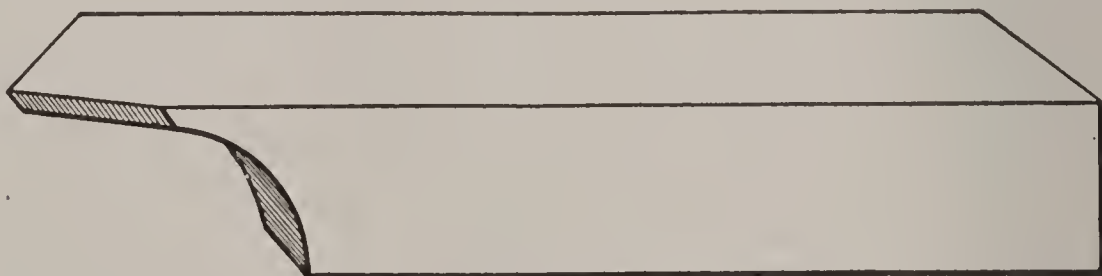


Fig. 61. Cutting Tool Used for Fluid Die

*Drilling.* Good results cannot be obtained by holding an ordinary drill in a chuck in the spindle of the tailstock of a lathe as there is too much spring due to play between the spindle and the hole of the tailstock, and due also to the spring of the drill, chuck jaws, and spindle of the tailstock, which is greatly increased as the distance from the point of the drill to the tailstock is increased. A mark, or a piece of wire is placed on the drill the desired distance from the point of the drill to act as a guide for the depth to be drilled. If the drill is too large to enter the tailstock chuck, a dog may be fastened to the shank of the drill, using a thin piece of sheet brass between the drill and the dog to prevent marring the drill, and, by placing the center of the tailstock in the center of the drill and allowing the tail of the dog to bear on the seat of the tool post, the hole can be drilled.

A tool should be fastened securely in the tool post of the lathe and the tail of the dog should just touch the tool when the center

of the tailstock is bearing on the drill center, and as the drill is fed into the work the carriage of lathe should also be moved along at exactly the same rate of speed, always keeping the tail of the dog bearing against the tool and also bearing on the seat of the tool post. If this is not done, the drill is likely to draw in, especially so if the drill passes clear through the work, and, as the drill catches or draws in, the center of the drill is pulled away from the lathe center in the tailstock, and the drill then rotates with the work. The object of having the tail of the dog bearing against the tool in the tool post is to enable the die-maker to hold the drill on the center of the tailstock. Under no circumstances should the dog be held by hand, either when drilling, or when removing the drill, while the lathe is rotating. The pressure and blow of the tail of the dog when a 1-inch drill catches in the work is sufficient to crush a hand or to sever a finger. Many fingers are lost in this manner.

It is appropriate to mention the danger when attempting to hold work by hand in drilling with a drill press. Always bolt the work to the table if the work is large or thin, or hold the work against a rigid stop on the drill-press table, and if the work is small it can be held in a large clamp or wrench. Thin work catches on a drill more often than heavy pieces, due to the point of the drill passing through the work before the body of the drill enters, and the work will run up the spiral of the drill to the end of the spiral, then rotate with drill. At times the work simply tilts at an angle and instantly assumes the same number of revolutions as the drill, and severe lacerations are the result if work is held by hand. The writer once had a  $\frac{3}{4}$ -inch drill catch in a drop-forge die block that weighed 112 pounds and the block was whirled, nearly upsetting the drill press, and finally the drill broke and the block was hurled some distance from the press. Emphasize again the tool-makers' slogan—"eliminate all chances".

*Boring to Form.* Having drilled the hole in the fluid die to proper depth, the form is now bored. This involves the use of a blanked piece of steel, *f*, Fig. 58, that was previously turned the exact shape desired or rather the shape of the desired cup. By using formed boring tools the impression in the die is made to absolutely fit piece *f* when the dies are closed. As the larger diameter of the die is *blind*, that is, cannot be seen when boring, the shape is deter-

mined by placing an even light coating of Prussian blue on the model piece *f* and rotating piece *f* when the die halves are bearing against it. A streak or streaks of blue will show in the die and by moving the movable half of the die the die-maker is enabled to see the work and to set the boring tool so that it will cut exactly on the streak of blue paint. This type of lathe work requires patience and skill, and several specially made boring tools of different radii.

*Forming with Cherry.* Another way in which this type of die can be made is to bore the die as above, almost to size and shape, and to finish the die in a drill press by having the model *f* of tool steel with teeth cut in it, *g*, Fig. 58, as in a formed milling cutter. The formed cutter, which is called a cherry, is hardened, and is gripped in a drill-press chuck, and the dies closed on the cherry. As the cherry revolves, the two halves which are held between clamps are closed onto the cherry, which cuts the desired form. The drill press must be stopped frequently and the clamp removed and the chips cleaned from the cherry, as there is no chip escape; plenty of oil should be used. If the design of die is not too intricate, however, the lathe method is quicker and in most cases better.

**Cutting Design.** Having obtained the desired shape in the die halves, the next operation is to cut the design. It is obvious that the hob method cannot be used in a die made in halves, as the design on *a*, Fig. 58, encircles the blank, and, if a hob were made having the design extending the entire circumference, the action of the hob when closing the two halves on it would be that the raised figures on the hob would cut away the die halves in a straight line. Therefore, the design must be cut in by hand, and the design must also be laid out in the die halves the reverse of that desired on the finished cup.

*Transferring.* There are several methods employed in transferring the outline of the design to the die. One method is to make a transferring roll, of material similar to printers' rolls and of the same shape but a trifle smaller in diameter than the bored portion of the die. The roll has a central hole its entire length, and larger in diameter at the top. The design is now sketched on a piece of thin paper which is exactly the same length as the circumference of that portion of the die having the figures, and after the design is

accepted the lines of the design are inked, using slow drying printer's ink, and the paper strip is pressed into a straight piece of wood which has been grooved the same shape as the contour of the die and the composition roll, as in Fig. 62. By rotating the composition roll from one end of the paper to the other the ink is picked up on the roll. Then, by cleaning the die thoroughly and placing the composition roll in the die and forcing a round plug in the small hole in the composition roll, the roll is expanded to fit the die and the ink from the roll is transferred to the die. This method only gives the general design and its location, as the ink will spread somewhat. With an engraver's point, which is a fine oil stone in the form of a

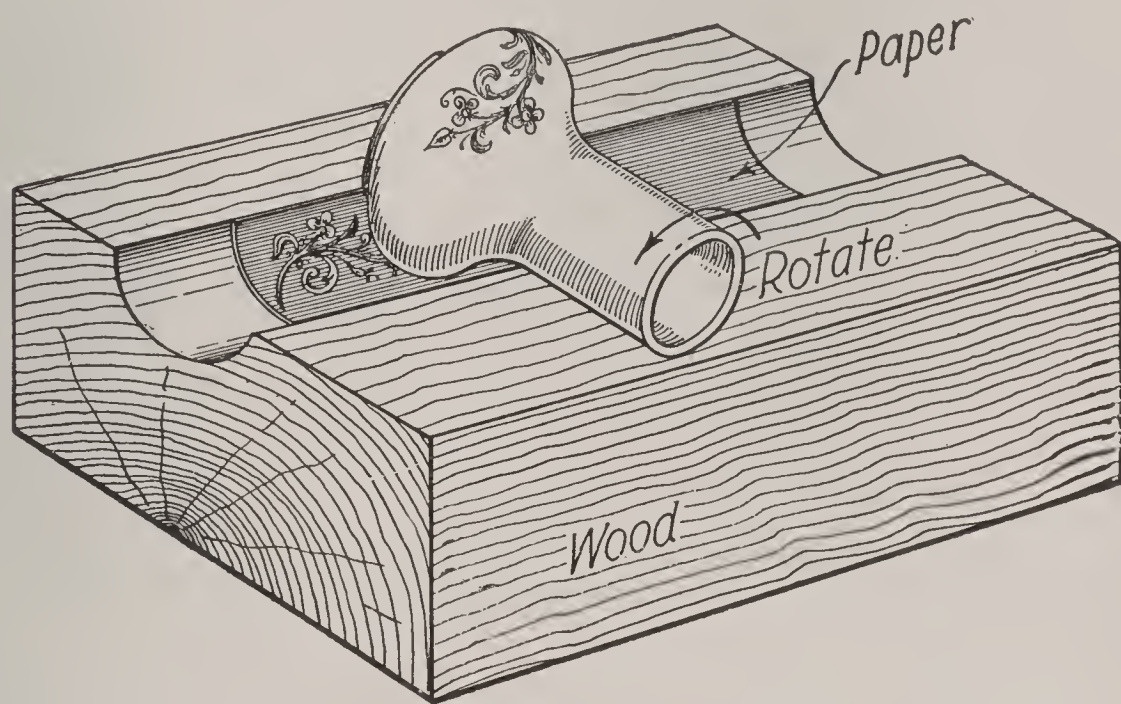


Fig. 62. Rolling Die with Composition Roll

lead pencil, or with a sharp scribe, the outline of the design is scratched in the die.

*Finishing.* From now on the work is strictly die-sinking and engraving, using small curved cold chisels to remove the bulk of the steel, shaping with engraving tools of various shapes, and lastly smoothing with files and wood stick with emery.

Die-sinker's wax is used for proving, and by smoking the surface of the die and forcing in the wax the impression as it should be on the cup is formed in the wax. The wax should be examined closely to find if any portion of the figure of the design is distorted, for an undercut on any part of the design will prevent the cup from being removed after being forced into the die.

## DROP-FORGING DIES

**Typical Operation.** When the term drop-forging dies is used it is generally understood to mean forging dies for forming red-hot metal. In operation these are two die blocks—upper and lower—as in Fig. 63. The upper half contains one half of the impression and the lower block the other half of the impression. The upper half is keyed to the hammer or drop by means of the dovetail shank, and the lower block is similarly secured to the bed of the drop press.

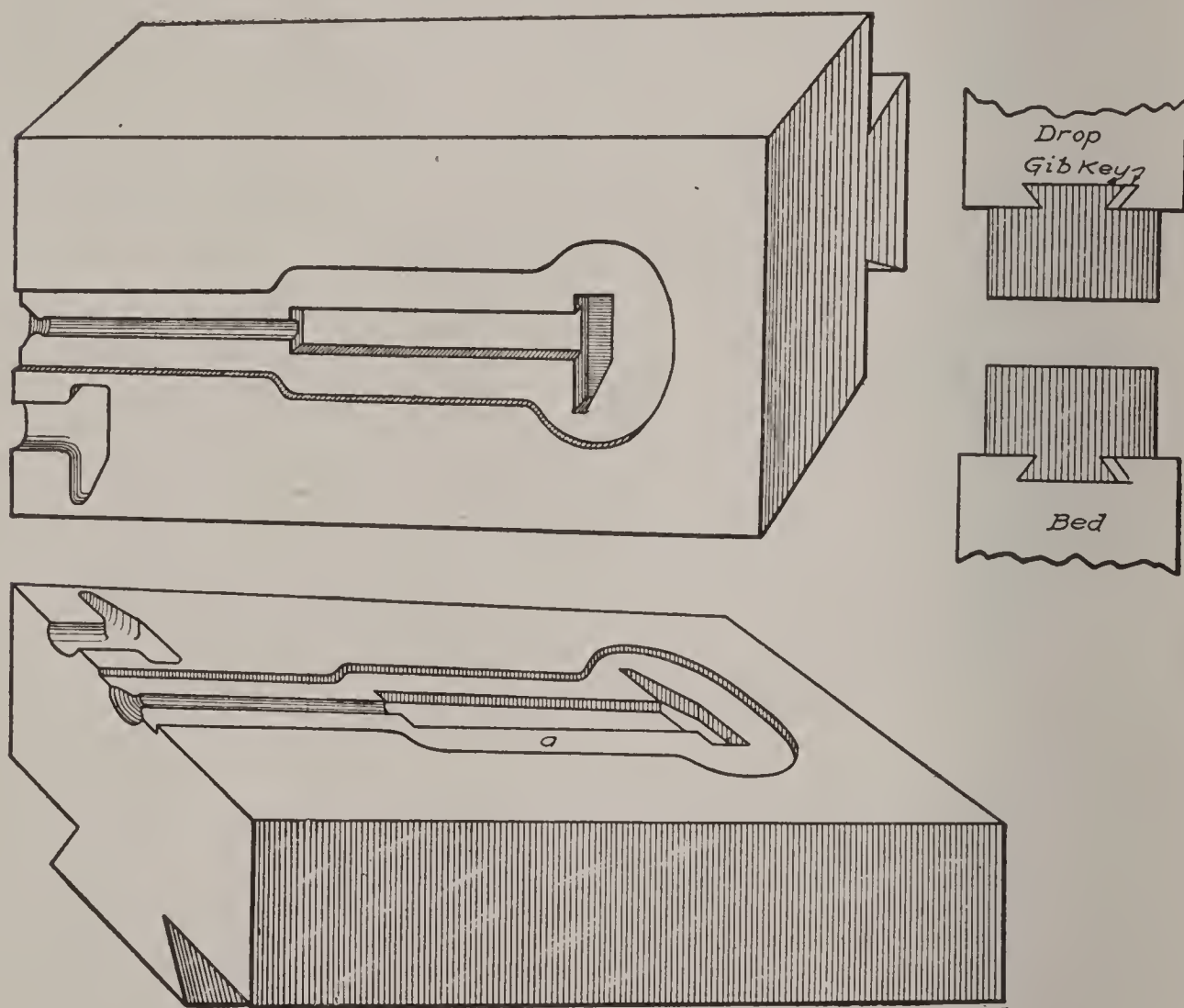


Fig. 63. Typical Drop-Forging Die

The impressions are so laid out that when one end and one side of each block are even the impressions are opposite.

**Breaking Down.** At one side of the impression proper is another impression called the break down. A furnace nearby contains a number of bars of metal which are heated on one end to a bright forging red. The red-hot end is placed over the break-down impression, and the drop is allowed to fall by tripping with a treadle. The blocks on coming together smash the heated bar into the break-down

impression. The object of the break down is to allow the use of a smaller bar of metal and by being formed in the break down the shape of the heated end is formed and flattened so that there is metal enough to fill the impression proper. The instant the blocks come together there is a rebound and the treadle should be released to allow instant raising of the drop which is lifted by a board fastened to it at one end. The board passes between two revolving pulleys that grip it, and the hammer is raised by friction to a slight distance above an automatic stop or pawl, at which point the rolls separate and the drop rests on the pawl.

*Forming.* The heated bar is now placed over the die proper, and enough blows are given the bar to fill the die completely. At

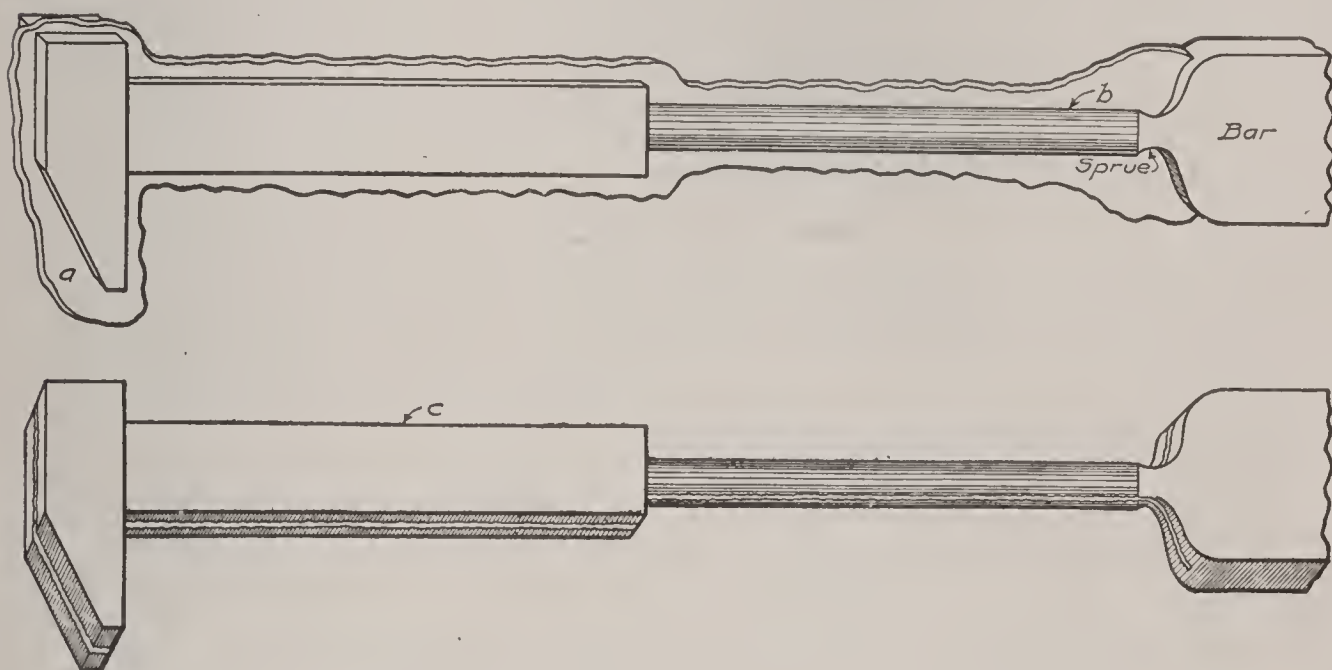


Fig. 64. Drop Forging Showing Flash Attached and Flash Removed

each stroke, however, the heated end should be raised from the die to allow the loose oxide or scale that may have formed to be blown or brushed from the lower die. Another reason for removing the bar a short distance from the die each stroke is to prevent heating the die unnecessarily. As there is generally more metal in the heated end than is necessary to fill the die, it is obvious that some of the metal will be forced out between the dies in a thin web—called the flash—*a*, Fig. 64. To permit the dies coming together and forming a piece to correct diameter, a recess, *a*, Fig. 63, is milled around the die for clearance for surplus metal or flash. There is a small connecting portion, *b*, Fig. 64, between the forged piece and the bar, called the sprue, which should be as small as possible.

*Trimming.* After the piece has been forged, it is then placed over a die having an open end to allow the passage of the sprue and called the trimming die, and the punch—being shaped to fit the forging to prevent its distortion—on descending, trims the flash from the forging and leaves the bar and forging as at *c*, Fig. 64.

The sprue is then placed between two knives that are chisel-shaped punches fitted in an ordinary punch press, and the finished forging is severed from the bar.

**Methods for Saving Material.** *Tapering.* If the work is of the type shown in Fig. 65, which is a bicycle crank having a large

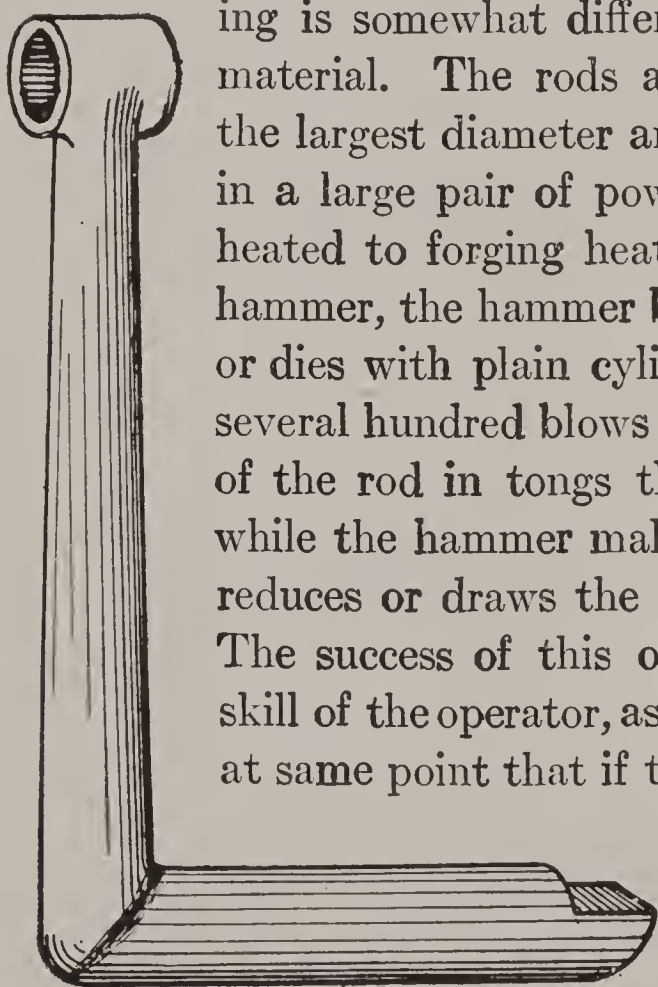


Fig. 65. Drop Forging with Tapered Stock

portion and tapering to a small end, the method of forging is somewhat different—mostly to effect a saving in material. The rods are purchased a trifle larger than the largest diameter and cut to short lengths while cold in a large pair of power shears. These pieces are then heated to forging heat and forged tapering under a trip hammer, the hammer being fitted with two small blocks or dies with plain cylindrical impressions, and making several hundred blows per minute. By gripping the end of the rod in tongs the rod is worked back and forth while the hammer makes rapid blows on the work, which reduces or draws the stock to proper length and size. The success of this operation depends solely upon the skill of the operator, as the blows are so rapid and always at same point that if the operator fails to move the rod

or turn it fast enough the work will not be round or tapered. In other words, the trip hammer produces the same work that a blacksmith would produce by

hand hammering except in much quicker time. The forged piece is bent at right angles, then reheated, and afterward placed in a drop die for final shaping.

*Spreading.* Fig. 66 shows another type of forging which is a sprocket wheel, and to produce this forging in one die would mean a tremendous loss of metal as the hub is so much thicker than the rim. If a thick piece of steel were placed over a center die and an attempt made to flatten the steel until it filled the die, it can be

readily seen that, as the stock began to flow outward toward the rim of the die, it would flow in all directions, and the metal that would be forced into the spokes would be gradually pushed sidewise, or distorted. Therefore a smooth-face breaking-down die is used to form the hub and to spread the steel enough to completely cover the finishing die, after which the steel is reheated and final-formed in the finishing die.

**Shaping Die Block. *Setting-Up.*** The first step in making drop dies is to select the die blocks; they must be large enough for the job, for the impression must not come too close to the edge of

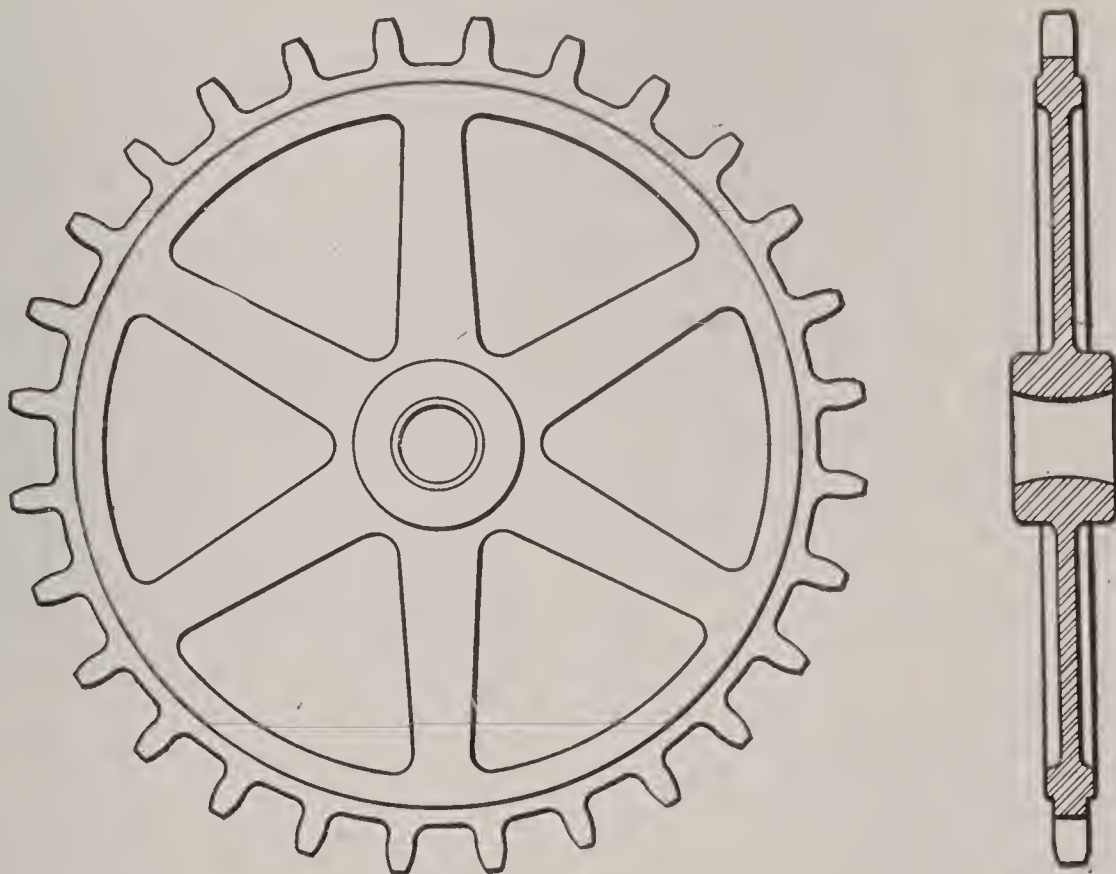


Fig. 66. Sprocket-Wheel Forging

the blocks. A hole, say  $\frac{5}{8}$  inch in diameter, is drilled in each end of each block about  $\frac{1}{2}$  inch deep and approximately central in the end. Then the block is placed, with its level surface down, on a planer bed, and with finger straps engaging the holes in the ends and properly blocked up, as in Fig. 67; the die block is now brought to bear against a parallel strip that is parallel with the travel of the bed and that is clamped to the planer bed. The object of this parallel strip is that it not only aligns the edge of the die block with the travel of the planer bed but prevents the block from shifting when planing on the extreme edge, which is likely to happen as the block

is clamped in the center by the fingers only. When a rough casting or forging is clamped to any machine bed or in any machine vise, it is good practice to place a thin piece of metal or cardboard between the clamped surfaces to prevent marring the machine surface. If the planer vise is large enough to hold the die block, there is of course no advantage in using finger straps and bolts, providing the solid vise jaw can be readily aligned with the travel of the bed.

*Forming Dovetailed Shank.* Having secured the block to the planer, a cut is taken across the top, and, chalking or coppering the

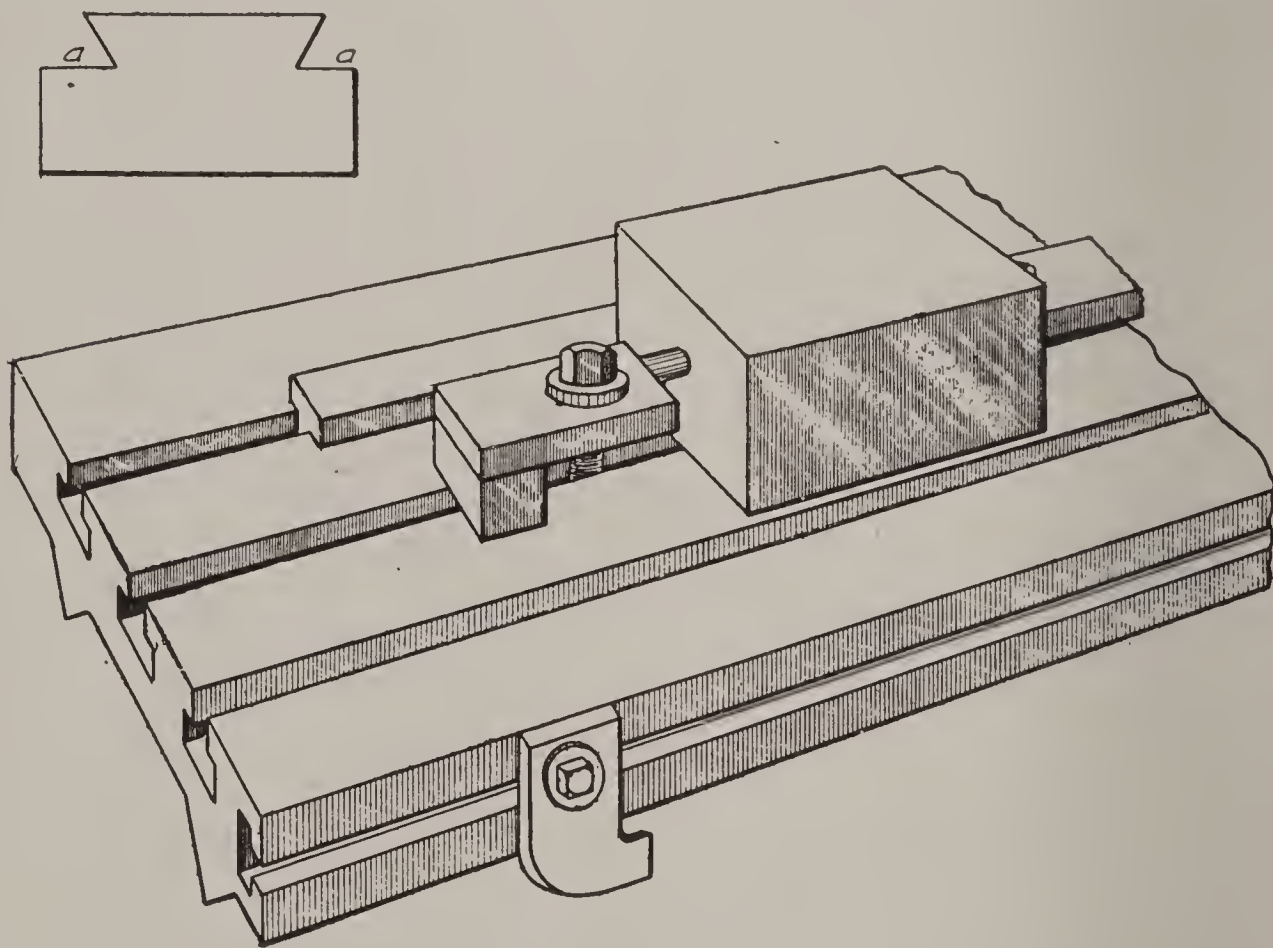


Fig. 67. Shaping Die Block for Drop Forging

top, the width of the dovetail is scribed on the face. The stock is then planed away and the angle forming the dovetail is planed. Should the angle be 30 degrees from the vertical the head of the planer is set at 30 degrees by means of the graduated dial, and the flop which carries the tool should also be set way over in the same direction that the head is swung, to prevent the tool gouging in on the back stroke. Some tool-makers lock the tool so that on the back stroke the tool drags in exactly the same line as on its forward or cutting stroke. This is not good practice, however, for the back drag causes more wear on the tool than the cutting or forward stroke.

The dovetail shank is planed to fit a templet, and the angular sides must be smooth and straight, for any irregularity of surface prevents the long taper key from properly holding the block. For instance, should several ridges stand out on the angular sides of the shank due to uneven planing, the key would bear only on these ridges, and after a few blows when in the drop press the ridges would be likely to flatten, causing the key to become loose. The shoulders *aa*, Fig. 67, must be on a line; in order to obtain the best results, both sides are roughed nearly to the line, and the last chip

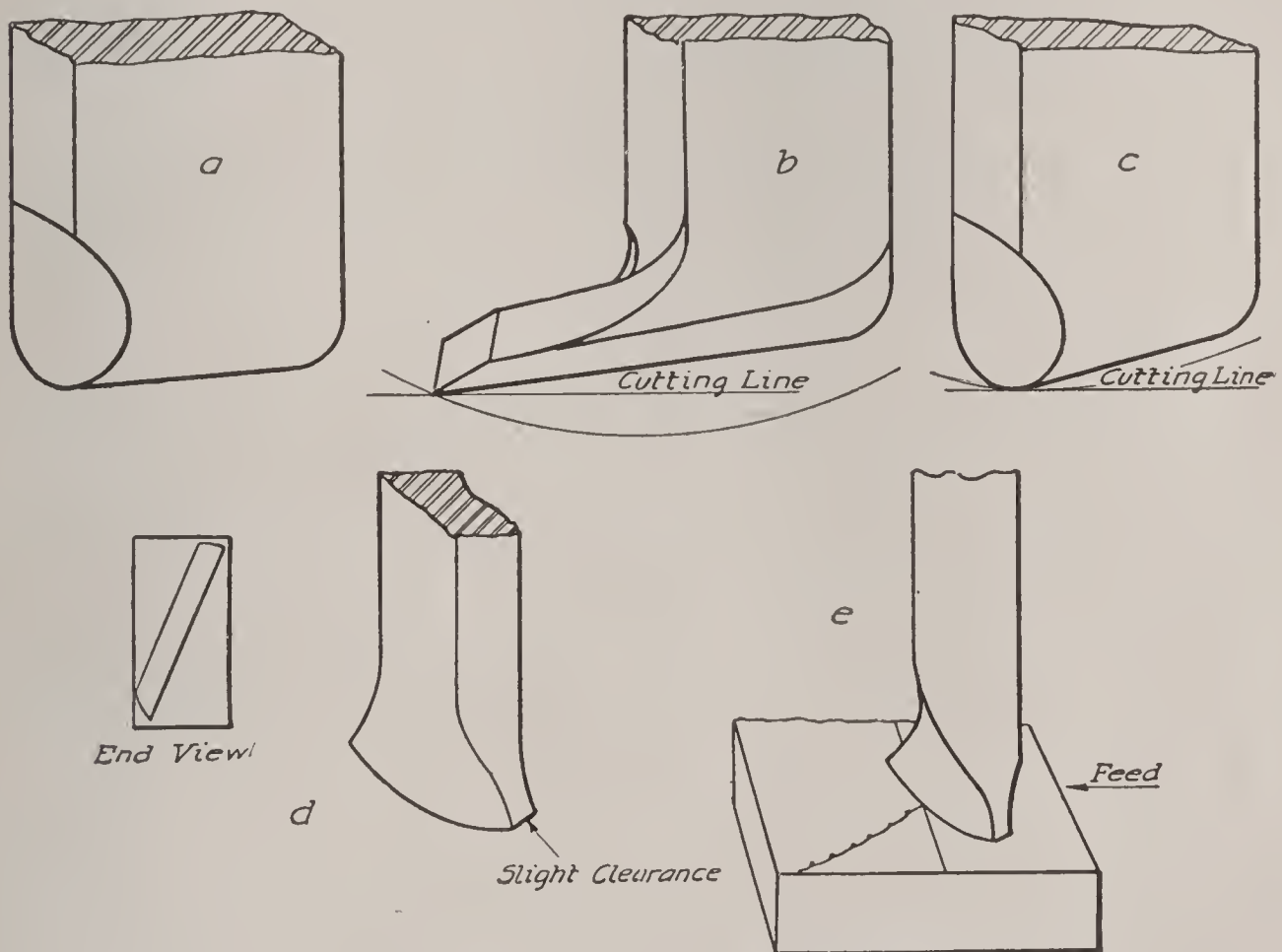


Fig. 68. Cutting Tools for Machining Die

is taken first on one side allowing the tool to start as close to the shank as possible and to feed out, then, without changing the elevation or position of tool, the head is moved over so that the tool is on the opposite side of the block, and a finish chip is taken. The angle sides are then roughed out, and the last chip should be light—a rigid keen cutting tool being used.

For roughing out any heavy work the roughing tool *a*, Fig. 68, is best adapted. The diamond point should not be used for heavy cuts unless the cutting point is on a line with the tool face that the tool-post screw bears against. By referring to sketch *b*, Fig. 68,

which is a diamond-point tool, the cutting point is seen to be so far advanced from the line of tool support that any springing of the tool would cause it to dig in, as will be understood by noting the line showing the radius traveled by the tool point in springing. It will be noted that the lowest point of the radial line is below the line of the cutting surface. By using a roughing tool, as at *c*, Fig. 68, the springing tends to force the tool away or above the cutting line.

*Machining Top and Edges.* Having fitted the shank to the templet, the straps can be removed and the die block fastened to the bed, shank down, and the edge of the shank brought to bear against the parallel strip. The top surface is machined sufficiently to obtain a true clean surface, and the final cut should be taken with a spiral finish tool, *d*, Fig. 68, for the top must have the die outline laid out on its surface, and a rough surface makes it difficult to see the scribed lines. The finishing tool when working is shown at *e*, Fig. 68.

One top edge of the block is machined by using the down feed to a distance of, say,  $1\frac{1}{2}$  inch on one side only. The block is then turned crosswise of the planer, and the top edge of one end is planed down the same distance. The machined edges of the end and side must be at right angles, for from these two machined surfaces—on both blocks—the dies are laid out, and the machined surfaces or edges are also used to set up the dies in the press by bringing the edges and ends in line with each other.

*Squaring.* One way to square up the block so that the machined edge will be at right angles is the old-fashioned cut-and-try method—that is, to set the block as nearly as possible by using two squares, one against the cross-head of the planer, and the other along the machined edge of the block. After the first cut is taken down, a square is tryed on the block and the block is shifted a trifle, etc., until the end and the side are square—the shop term for being at right angles. This is a slow method, and a more workmanlike one is to clamp an indicator to the planer tool held in the tool post, allowing the pointer of the indicator to travel along the edge of the square blade while the base of the square is held against the side of the block. The pointer of the indicator will remain at the same point when the block is exactly square.

**Recessing of Die.** *Laying Out.* After finishing the tops and

the edges of both blocks the top surfaces of each are smoothed with emery cloth on a file. A center line is drawn lengthwise of each block by using a sliding-blade square as at Fig. 69 and a cross-center line is scribed also. Scribing the line on each block with the

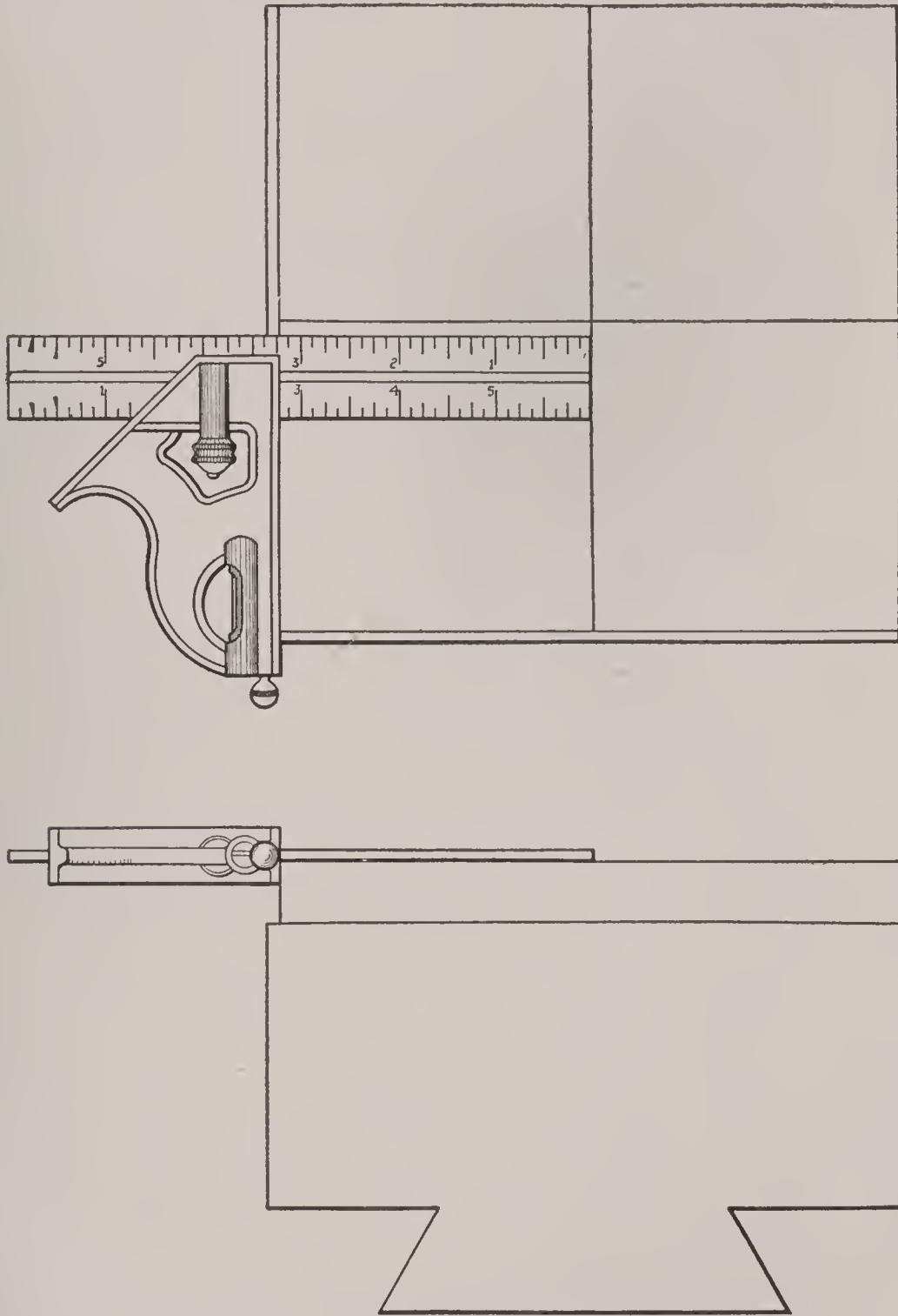


Fig. 69. Sliding-Blade Square Used for Laying Out

same respective settings of the square—working from the end and side of each block, and scribing along the end of the blade of the square—insures the center of the cross-lines being the same on both blocks.

Assuming that the die is to be laid out to produce the forging of the sprocket wheel shown in Fig. 66, the first move is to place a

fine prickpunch mark at the intersection of the lines on both blocks. As this particular forging is round, both blocks may be laid out exactly alike, but in the laying-out of forgings, such as Figs. 64 or 65, the outline of the forging must be laid out right and left, so that the outlines will match when the faces of the blocks are together. The center circle for the hub is scribed with dividers, as are also the circles for the rim, the inner diameter of rim, the circle for the diameter at the bottom of the teeth, and the outside diameter. The

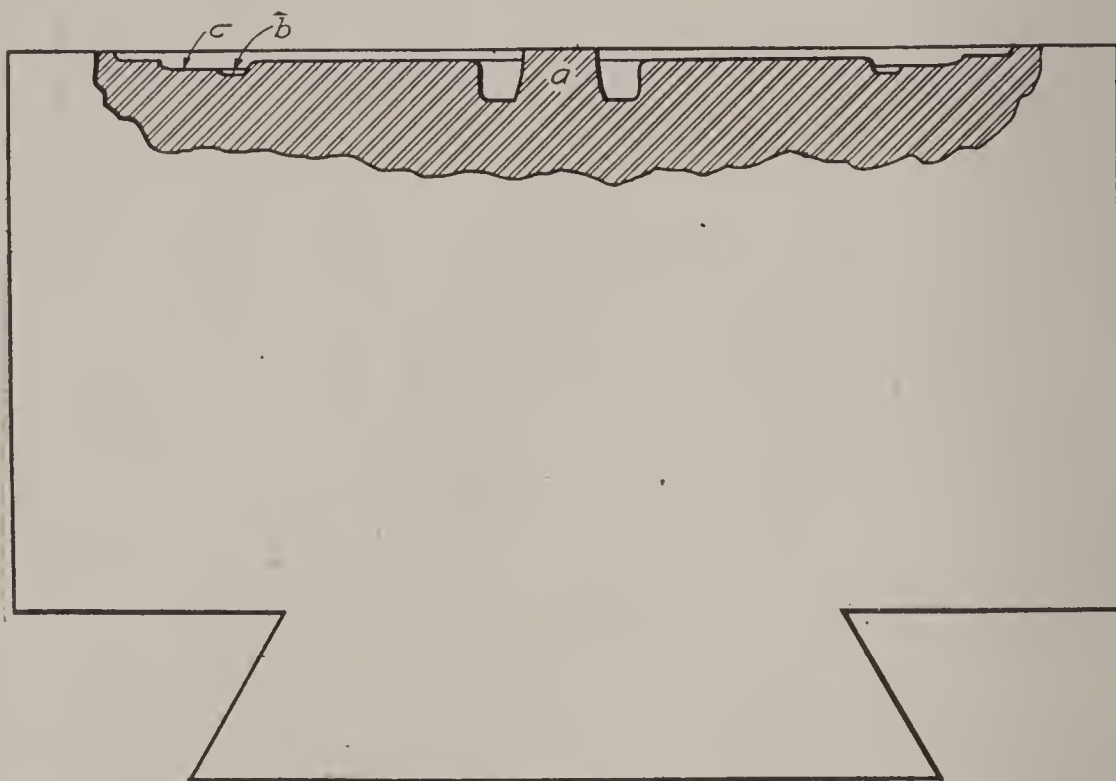


Fig. 70. Elevation of Die Block, Showing Shape of Lugs, Etc.

spokes are now laid out at right angles with each other, using a sliding-blade square.

If there is a dividing head on the milling machine or die-sinking machine, it is unnecessary to lay out the teeth, as a cutter of the right shape may be used and a tooth can be cut into the outside line, then the index shifted for the next tooth, etc. If it is necessary to cut the teeth by hand, then of course each tooth must be carefully laid out.

*Forming.* The die block is fastened to lathe the faceplate, and the prickpunch mark is indicated true. The recess for the hub of the forging is turned in the block the proper depth and tapering. Usually 5 degrees clearance is given on drop-die work of ordinary depth, and if the forging is somewhat deep, say 2 inches, 10 degrees is better; it is obvious that straight sides in the die would cause the

metal to stick so that the red-hot bar would not be stiff enough to pry the forging from the die. The center lug *a*, Fig. 70, for forming the hole in the hub may be made solid or inserted, as suits shop practice. At the same setting the rim *b* and the flash clearance *c* are turned in the die. When turning the rim it is well to use a formed turning tool that gives the proper angle to the side of the rim and at same time shapes the bottom of the rim.

The spokes are milled or cut in the shaper. The spokes and teeth can best be done on a die-sinking machine, which is a vertical milling machine having the dividing head on a table in the horizontal plane.

Dies for forging sprockets and similar work are extremely simple to make as the work is mostly lathe work. The die for producing the monkey wrench, Fig. 63, and for the crank, Fig. 65, are also easy to make, as the die can be cut out in a shaper or a milling machine, except for the sharp corners which have to be chipped out by hand using a cold chisel and hammer.

**Completion of Die.** *Shrinkage Allowance.* As steel in the molten state shrinks  $\frac{1}{8}$  inch per foot when cold, every dimension given on the blue print must be increased at the rate of  $\frac{1}{8}$  inch per foot to allow for shrinkage. For instance, if the finished diameter of the sprocket forging, in Fig. 66, called for 12 inches, the diameter of the corresponding recess on the die in Fig. 70 should be  $12\frac{1}{8}$  inches, or if the diameter is 6 inches, then allowing for shrinkage the die must be  $6\frac{1}{16}$  inches, and if the forging is to be 3 inches the die must be  $3\frac{1}{32}$  inches, etc. There are shrink rules or scales on the market that instead of being 12 inches long are  $12\frac{1}{8}$  inches long, but the graduations are the same style as on an ordinary scale—in inches, from 1 to 12. In other words, the  $\frac{1}{8}$ -inch shrinkage allowance is taken care of by being evenly distributed throughout the  $12\frac{1}{8}$  inches. All that is necessary, with this scale is to set the dividers to, say, 6 inches on it, and they are really set at  $6\frac{1}{16}$  standard inches.

*Matching.* When making drop dies having round or tapered parts, as in Fig. 65, it is a good plan to turn up a piece of steel at the proper taper, or to the proper diameter if the work is straight, and to use this piece as a templet, with which, by placing an even thin coating of Prussian blue on the templet, the trueness of the recess in the die can be tested frequently. When both halves of the die are

finished and the impressions are smoothed nicely, the blocks may be placed face to face, and, after slightly warming the blocks, the impression may be filled with molten babbitt. Babbitt does not shrink very much and the babbitt test piece may be examined to make sure that the impressions in each die match. Also the babbitt may be measured to check diameters and length.

*Hardening.* The dies are hardened by being heated face down on a charcoal fire, and, when heated to a depth of several inches, by having a heavy stream of water played on the face of the die. Cast-iron dies may be used when only a few hundred forgings are required.

**Dies for Trimming.** Trimming dies are usually made in halves to facilitate making, and are also frequently made of machine steel and casehardened as the forging is red hot when trimmed. If the forging is thin or light, the flash would cool so quickly that soft dies would be out of the question. The punch, however, can be case-hardened.

The clearance on trimming dies varies from 5 degrees to 10 degrees, according to the nature of the forging. In any case the forging must be able to pass through the die without being distorted. Trimming dies are open at one end to allow the sprue and rod to pass through, for the forging should stay on the rod as it often happens that the forging becomes distorted during trimming and it is necessary to strike it between the drop dies for final shaping of the forging.

# INDEX



# INDEX

---

## B

	PART	PAGE
Bench micrometer .....	I,	49
Blanking and shearing die .....	II,	2
alignment of stripper .....	II,	5
die block, preparing .....	II,	8
die shoe .....	II,	20
die stock .....	II,	7
finishing of die .....	II,	16
forming of punch .....	II,	17
gang dies .....	II,	44
hardening of die .....	II,	15
laying out die .....	II,	10
laying out punch .....	II,	16
making die bushing .....	II,	3
making die shoe .....	II,	4
sectional dies .....	II,	32
shaping of die .....	II,	11
shearing dies .....	II,	51
size factor .....	II,	2
binding .....	II,	3
clearance .....	II,	2
guiding .....	II,	3
resistance of sheets .....	II,	2
sub-press dies .....	II,	20

## D

Depth gage .....	I,	49
Dies .....	I,	13
finishing .....	II,	16
hardening .....	II,	15
laying out .....	II,	10
shaping .....	II,	11
Die block .....	II,	8
Die bushing, making .....	II,	3
Die-making and usage .....	II,	1
Die shoe .....	II,	20
Dies and sheet-metal stamping .....	II,	1-86
Drawing dies .....	II,	59
blank, finding size of .....	II,	59
irregular .....	II,	62
operation points .....	II,	61
types of .....	II,	60
Drop-forging dies .....	II,	76
completion of die .....	II,	85

	PART	PAGE
Drop-forging dies (continued)		
operation .....	II,	76
recessing of die .....	II,	82
saving material .....	II,	78
shaping die block .....	II,	79
trimming die .....	II,	86
E		
Embossing dies .....	II,	65
die sinking .....	II,	66
jewelry dies .....	II,	68
F		
Fluid dies .....	II,	68
cutting design .....	II,	74
forming of die .....	II,	71
operation of .....	II,	68
substitute processes .....	II,	70
usage .....	II,	68
G		
Gages, types and design of .....	I,	44
depth .....	I,	49
limit .....	I,	44
micrometer .....	I,	49
plug .....	I,	46
profile .....	I,	49
receiving, making of .....	I,	46
snap .....	I,	45
Gang dies .....	II,	44
J		
Jigs and fixtures, design of .....	I,	35
design essentials .....	I,	39
drilling fixtures .....	I,	35
spring-pump locators .....	I,	37
V-type jig .....	I,	36
jigs in general, design of .....	I,	43
rapid operation, devices for .....	I,	39
drilling and reaming with same jig .....	I,	41
hinged covers .....	I,	39
indexing .....	I,	41
master plate .....	I,	42
multi-spindle operation .....	I,	40
screw bushing .....	I,	40
slip bushing .....	I,	41
sequence of operations, proper .....	I,	38
L		
Limit gage .....	I,	44

## M

	PART	PAGE
Micrometer gages.....	I,	49

## P

Plug gage.....	I,	46
Profile gage.....	I,	49
Punches.....	I,	13
forming of.....	II,	17
layout.....	II,	16
Punches and dies, design of.....	I,	13
blanking types.....	I,	13
combination.....	I,	17
piercing-and-blanking.....	I,	13
sub-press.....	I,	16
drawing and forming types.....	I,	19
blanking-and-drawing.....	I,	20
deep-drawing.....	I,	26
double-action.....	I,	24
drawing, simple.....	I,	19
embossing.....	I,	30
extruding.....	I,	30
fluid.....	I,	34
forming.....	I,	31
shaving.....	I,	27
Punches and dies, types of.....	I,	13

## R

Receiving gage.....	I,	46
Roller dies.....	II,	71

## S

Screw-machine forming.....	I,	6
Sectional dies.....	II,	32
advantages.....	II,	32
attaching piercing punches.....	II,	41
construction requirements.....	II,	34
laying out.....	II,	32
making blanking punch.....	II,	42
making of die.....	II,	36
shaping of die.....	II,	33
Shearing dies.....	II,	51
making lower punch.....	II,	54
making upper punch.....	II,	57
two-punch principle.....	II,	51
Snap gage.....	I,	45
Stripper.....	II,	19
Sub-press dies.....	II,	20
assembling parts.....	II,	31
fitting piercing punches and dies.....	II,	28

Sub-press dies (continued)	PART	PAGE
making plunger .....	II,	24
making press body .....	II,	22
making small parts .....	II,	25
round holes, placing .....	II,	29
special cutters, use of .....	II,	27
typical features .....	II,	20
T		
Tool design .....	I,	1-59
gages .....	I,	44
jigs and fixtures .....	I,	35
punches and dies .....	I,	13
selection of type in .....	I,	1
successful process in .....	I,	49
accuracy, conditions for .....	I,	55
collaboration .....	I,	58
handling and machining methods .....	I,	51, 54
observation .....	I,	59
outlining methods .....	I,	56
product design .....	I,	57
relation of operations, proper .....	I,	49
Tool types, selection in design of .....	I,	1
method, example of .....	I,	1
basis, production .....	I,	1
dies, relative advantages of .....	I,	6
drill jig, box .....	I,	5
milling fixtures .....	I,	3
turning, turret machine .....	I,	6
requisites of designer .....	I,	13
Trimming dies .....	II,	86







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